

THE INSTITUTION OF PRODUCTION ENGINEERS JOURNAL



APRIL 1971

THE INSTITUTION OF PRODUCTION ENGINEERS JOURNAL

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CONTENTS

THE 1957 VISCOUNT NUFFIELD PAPER

"TECHNICAL EDUCATION FOR PRODUCTION ENGINEERS" by The Rt. Hon. The Lord Hives, C.H., M.B.E., D.Sc., LL.D.	207
REPORT AND DISCUSSION	217
CORRESPONDENCE	223

SIXTH CONFERENCE ON AIRCRAFT PRODUCTION

Session III

"SOME ASPECTS OF THE DESIGN, DEVELOPMENT AND MANUFACTURE OF THE P1 WING" by F. Bradford, A.F.R.Ae.S., and G. H. Taylor	226
REPORT AND DISCUSSION	245

Session IV

COMBINED DISCUSSION	248
-------------------------------	-----

"OUTPUT PATTERN IN REPETITIVE TASKS" — with special reference to Compensating Relaxation Allowances (Part II) by N. A. Dudley, Ph.D.(Birmingham), B.Sc.(London), M.I.Prod.E.	257
--	-----

Notice of Council Elections, 1958 - 1959	264
--	-----

PERA QUARTERLY NEWSLETTER	265
-------------------------------------	-----

EXTRACTS FROM REGION AND SECTION REPORTS	267
--	-----

INSTITUTION NOTES	273
-----------------------------	-----

NEWS OF MEMBERS	274
---------------------------	-----

HAZLETON MEMORIAL LIBRARY — Additions	275
---	-----

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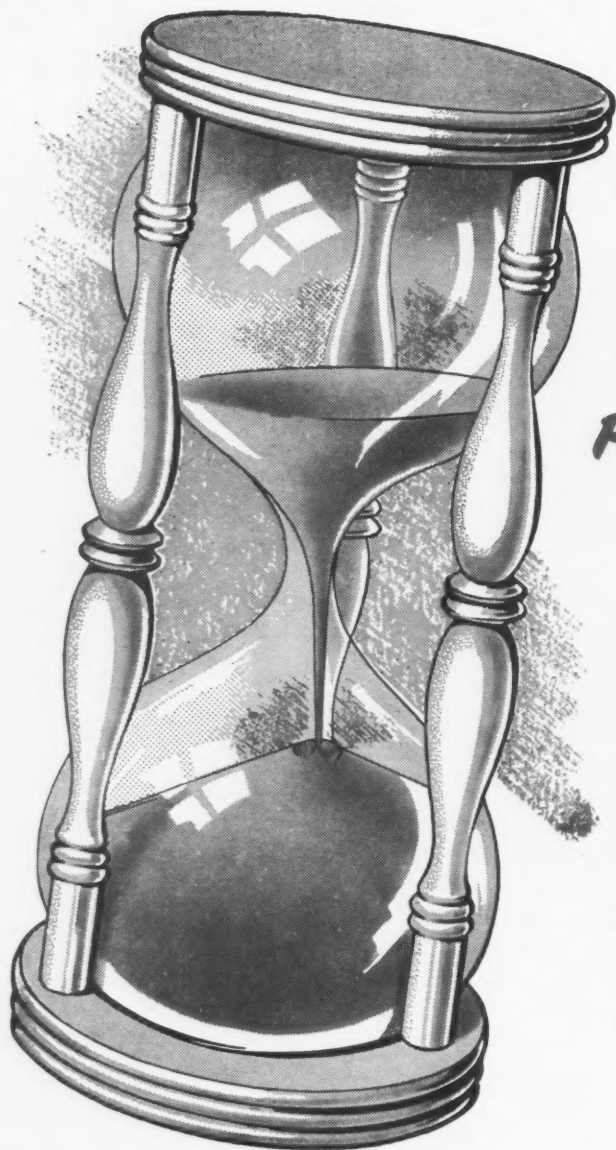
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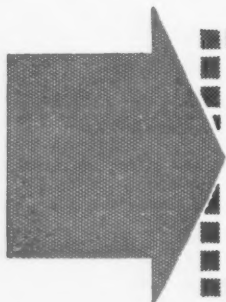
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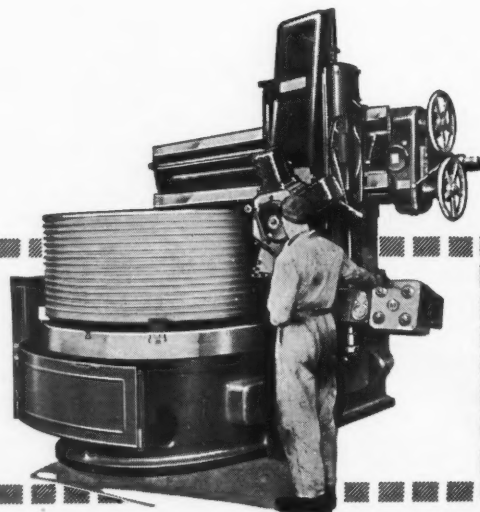
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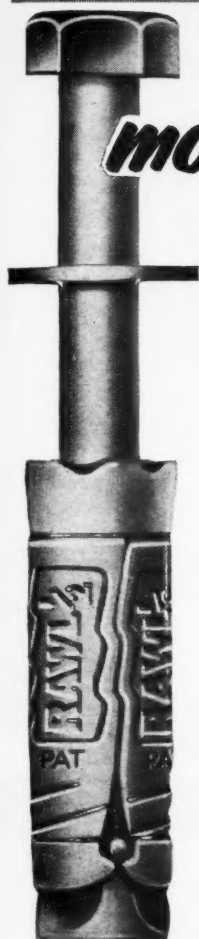
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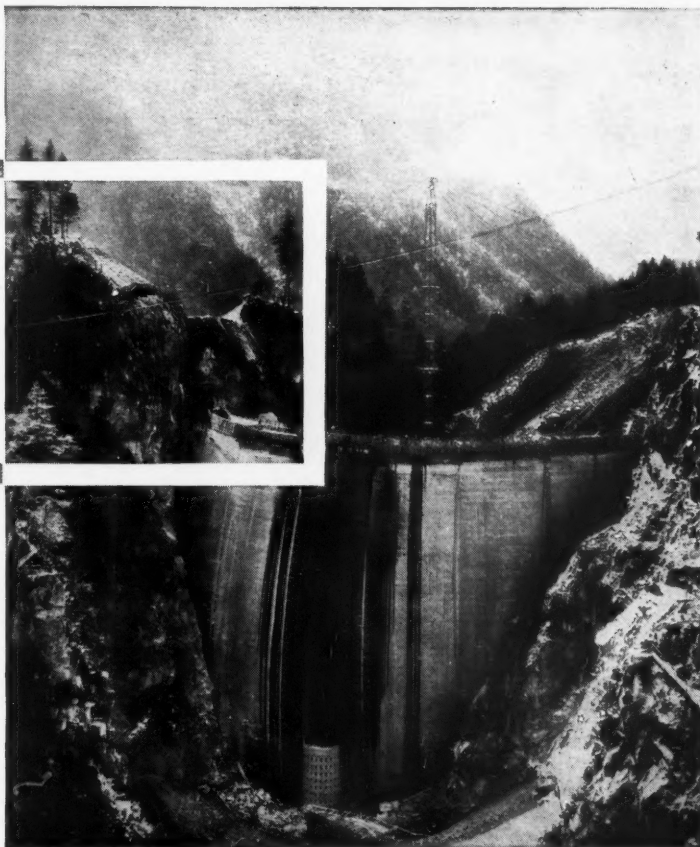
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and Hexagonal Nuts
and Round Nuts
with or without Slot

Separating Workpieces

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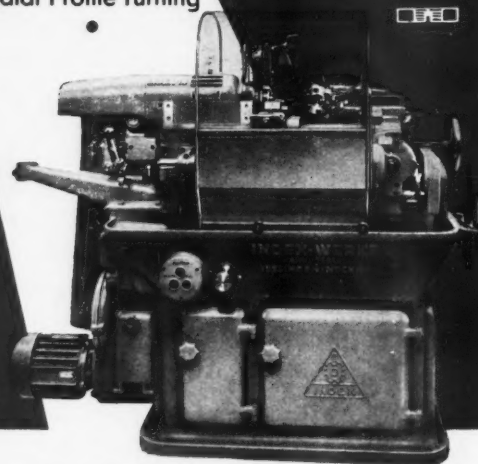
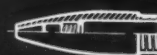
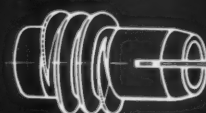
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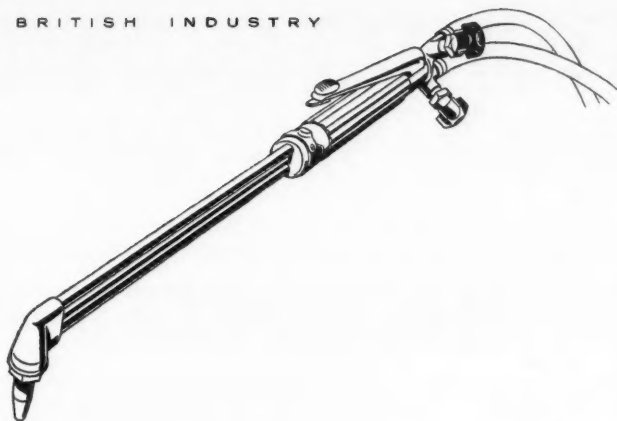
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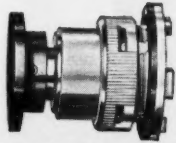
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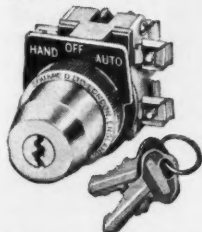
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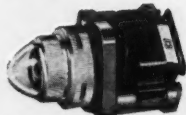
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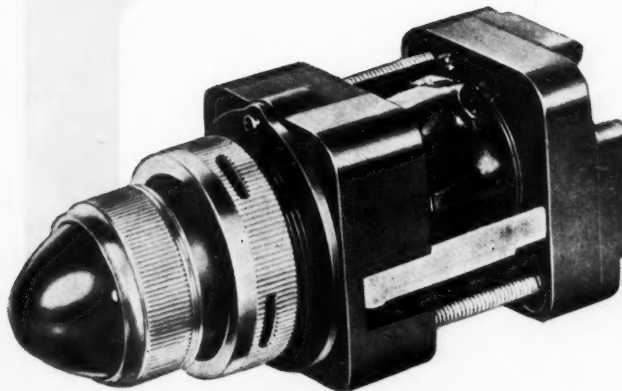


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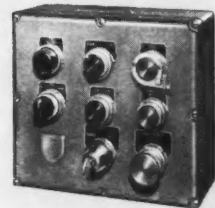
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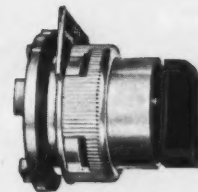
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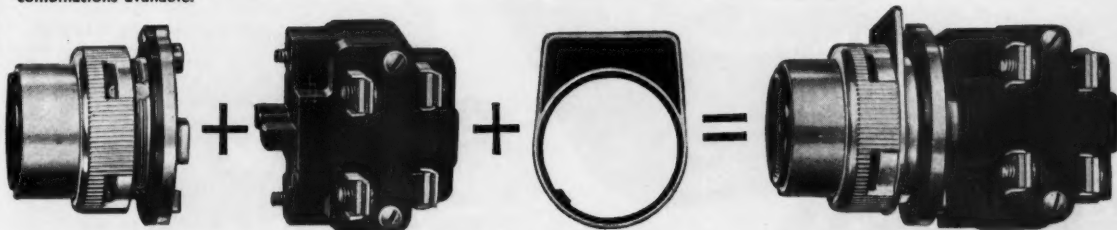
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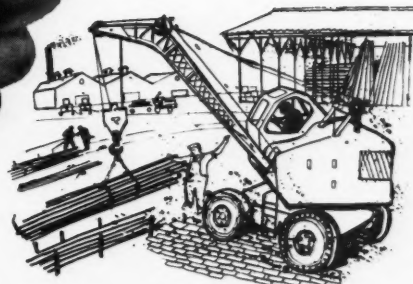
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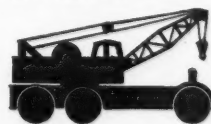


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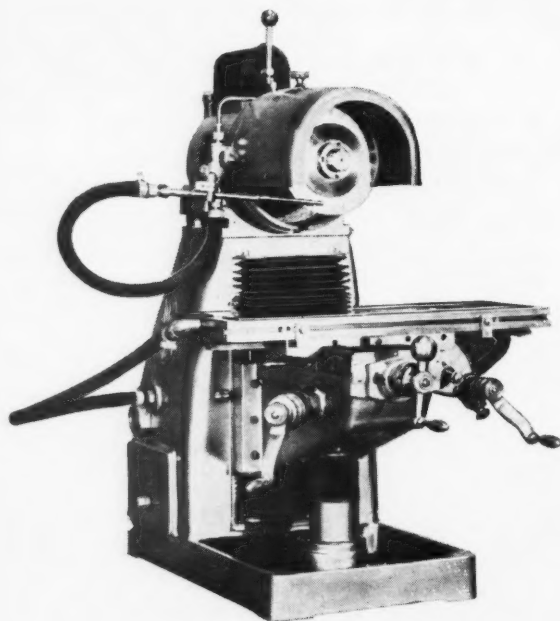
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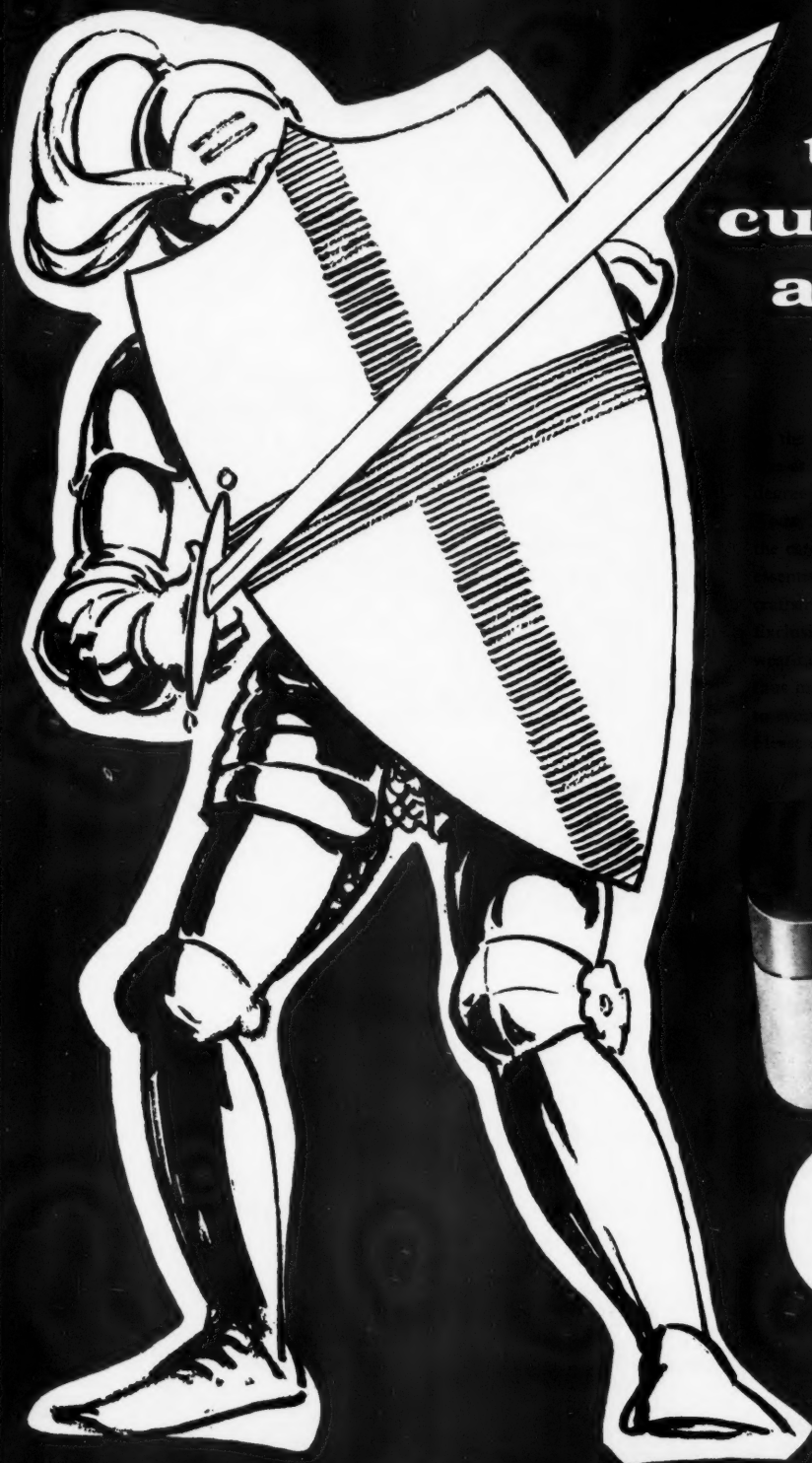
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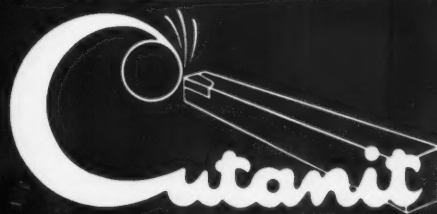
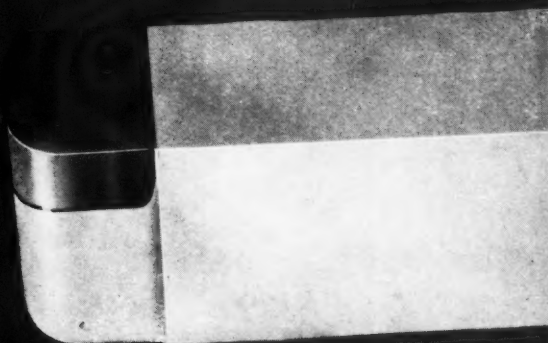
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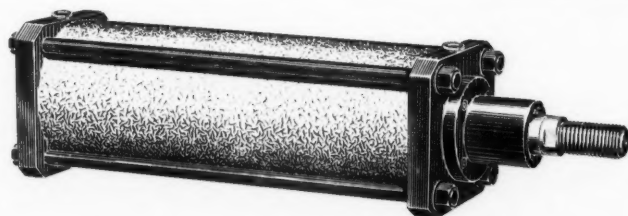
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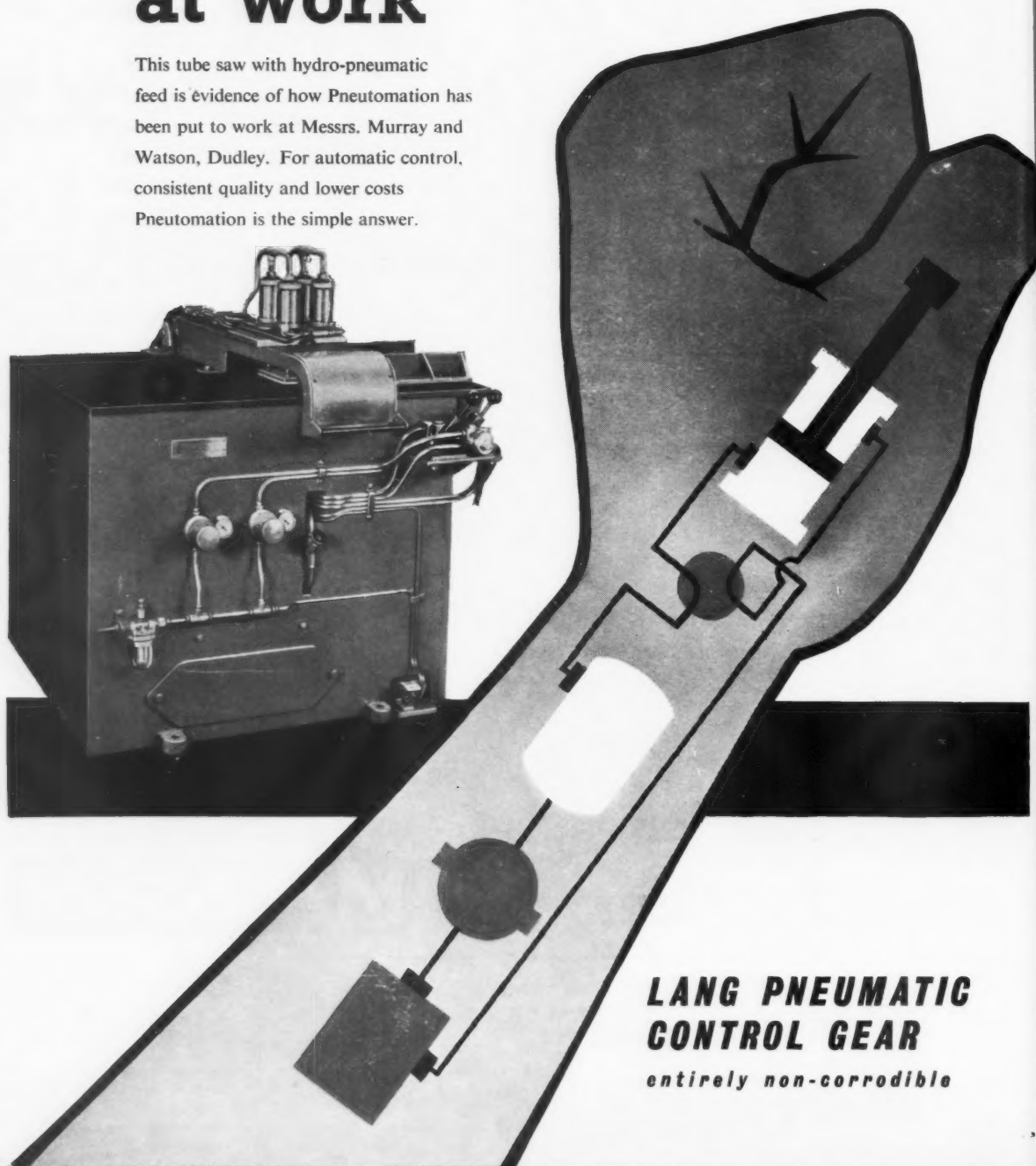
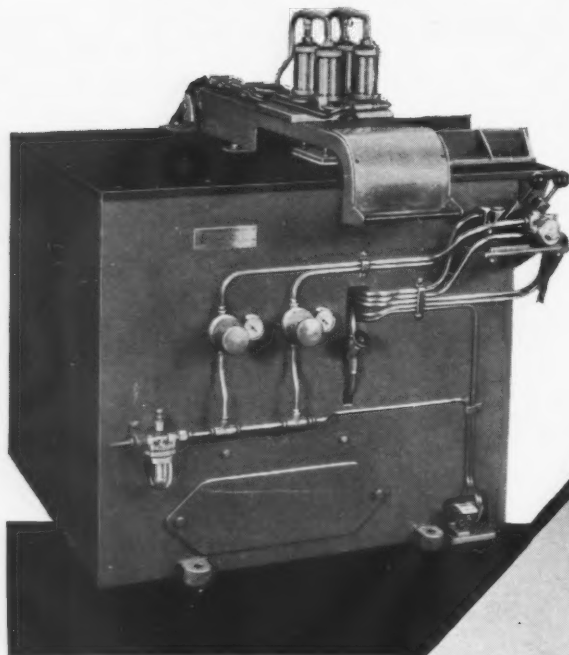
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A black and white photograph of various industrial polishing machines. The machines are arranged on a tiled floor. In the foreground, there are several polishing wheels and a small tool. Labels are placed around the machines: 'Morrisflex' in a large, stylized script at the top; 'BACKSTAND IDLER' on a machine to the left; 'DUAL SPEED' on a machine in the center; '3-HP' and '6-HP' on machines to the right; and 'BENCH BACKSTAND' on a machine in the foreground. A small label on one of the machines reads 'BUILT IN COVENTRY ENGLAND'.

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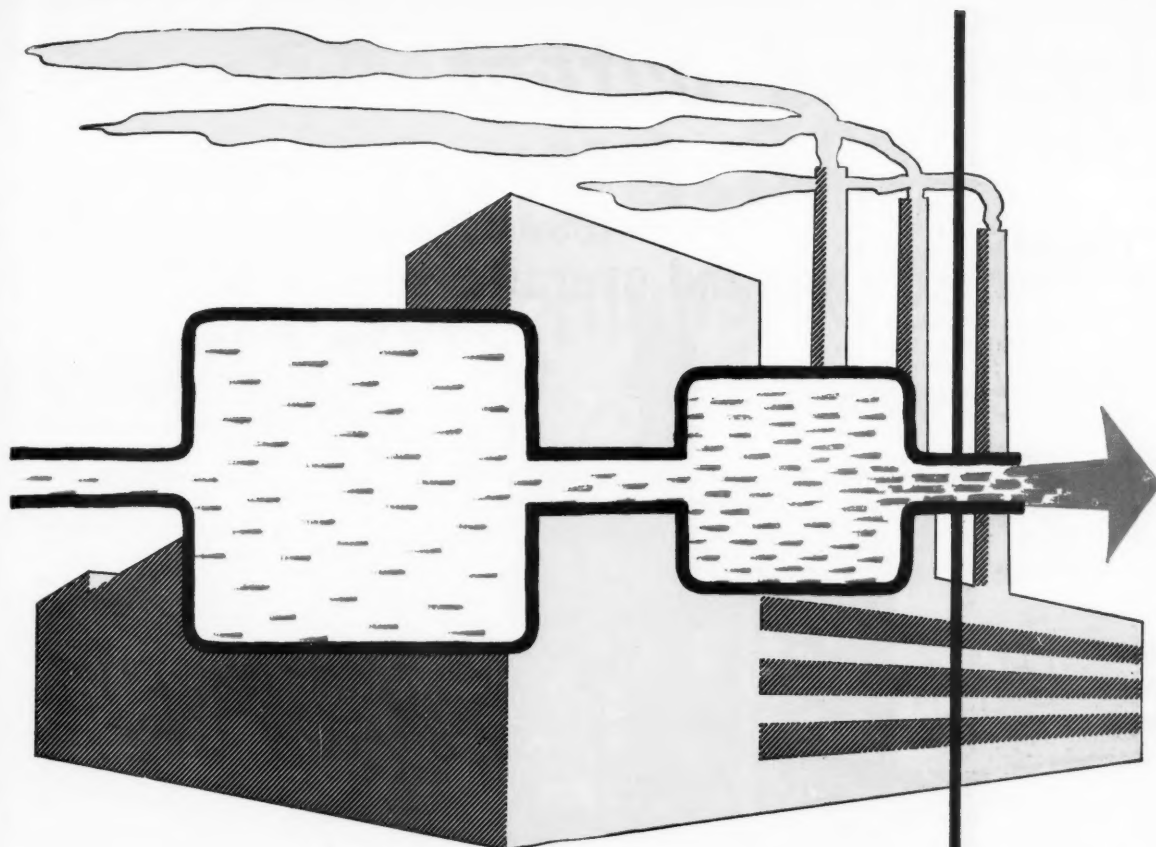
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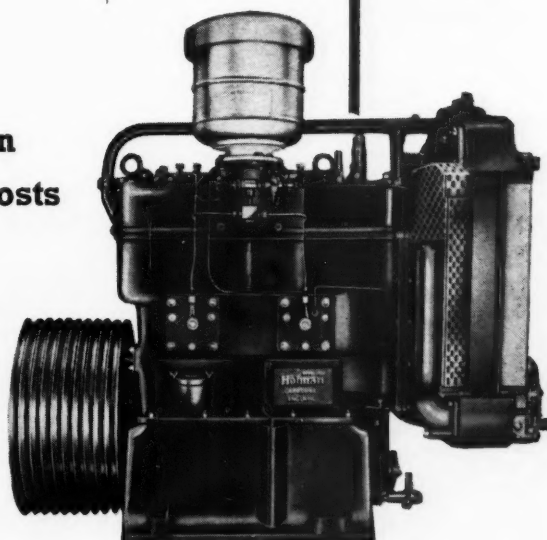


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5 ft. Wet Base



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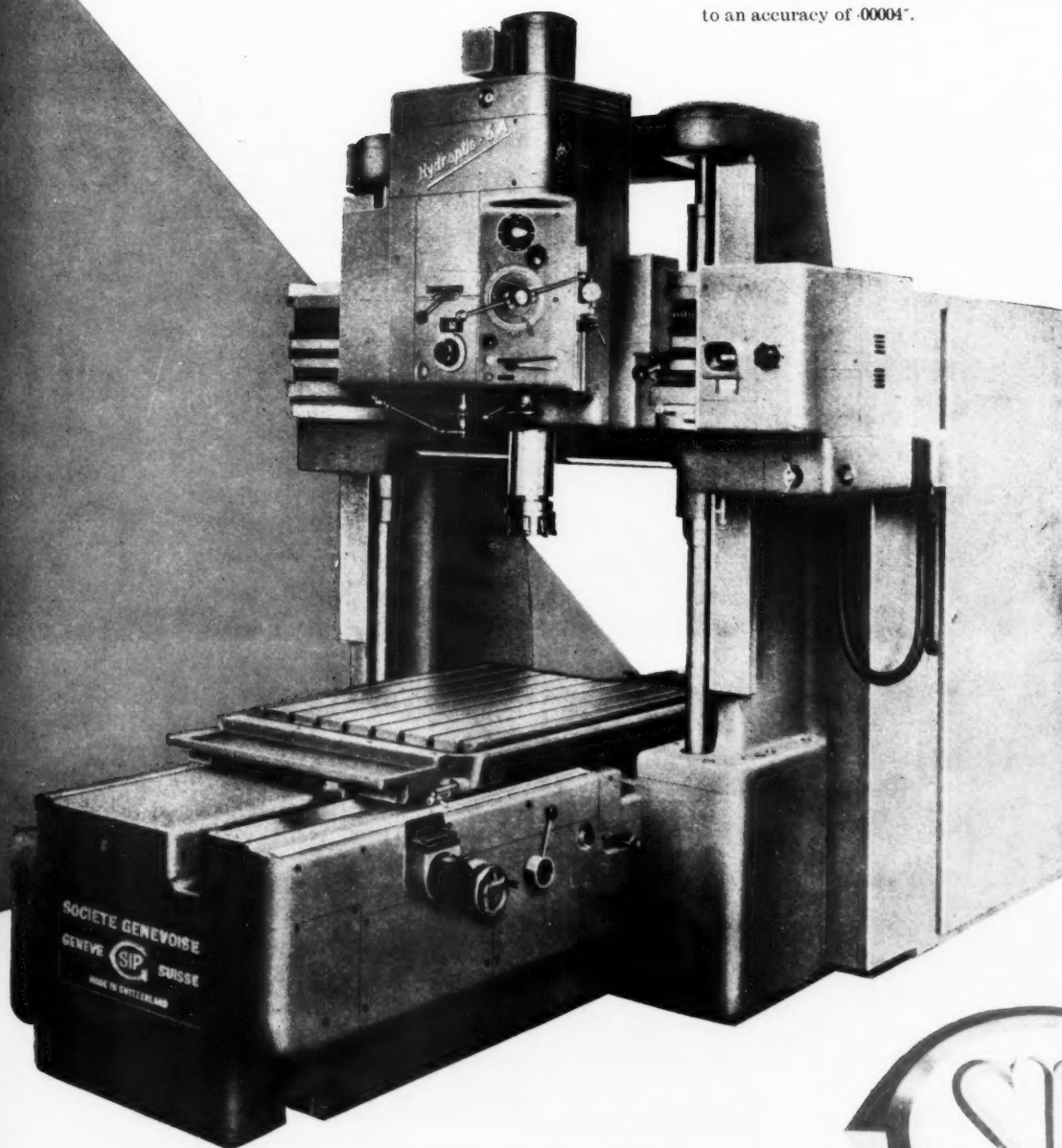
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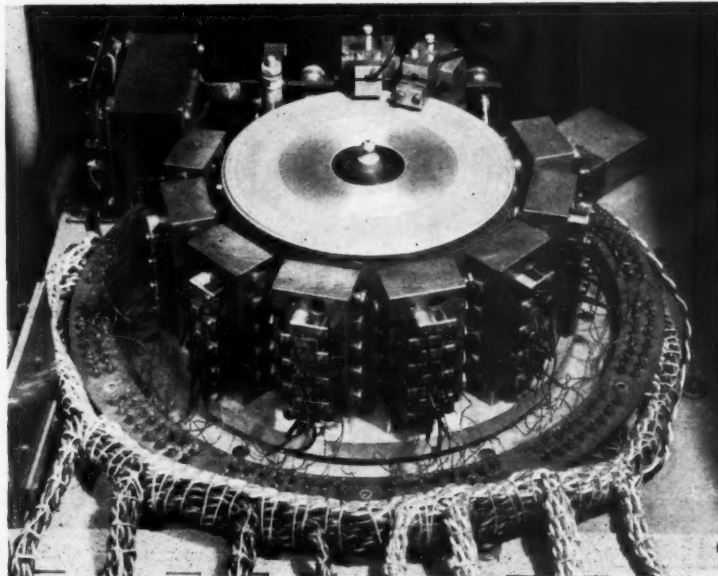
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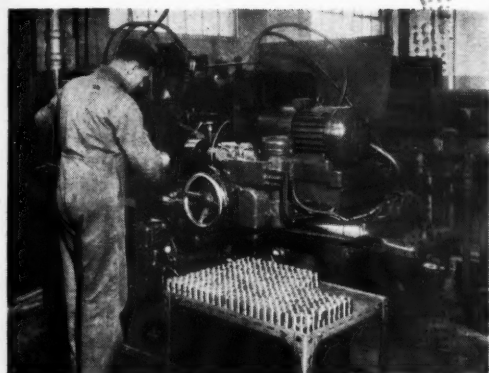
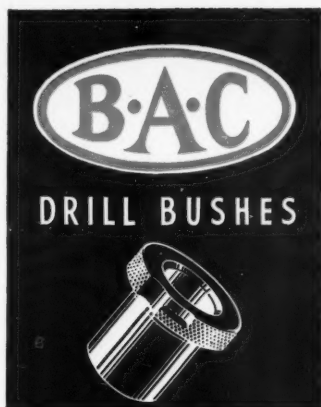


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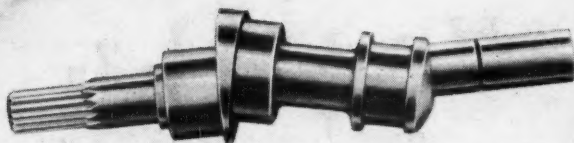
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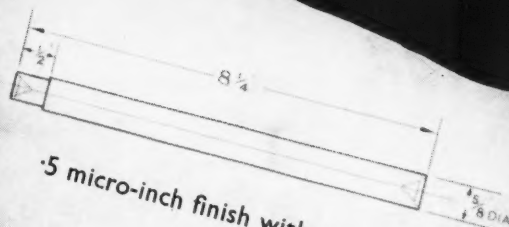
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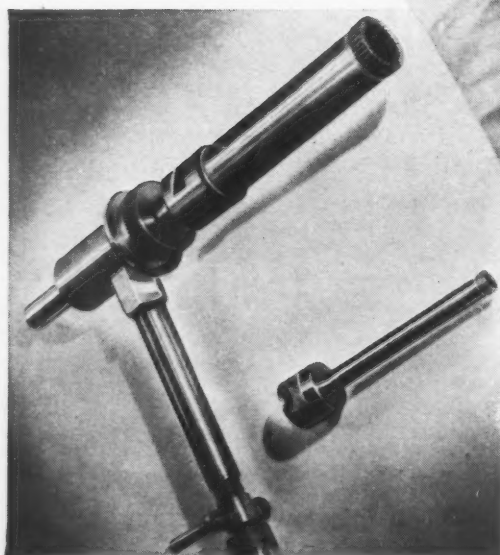
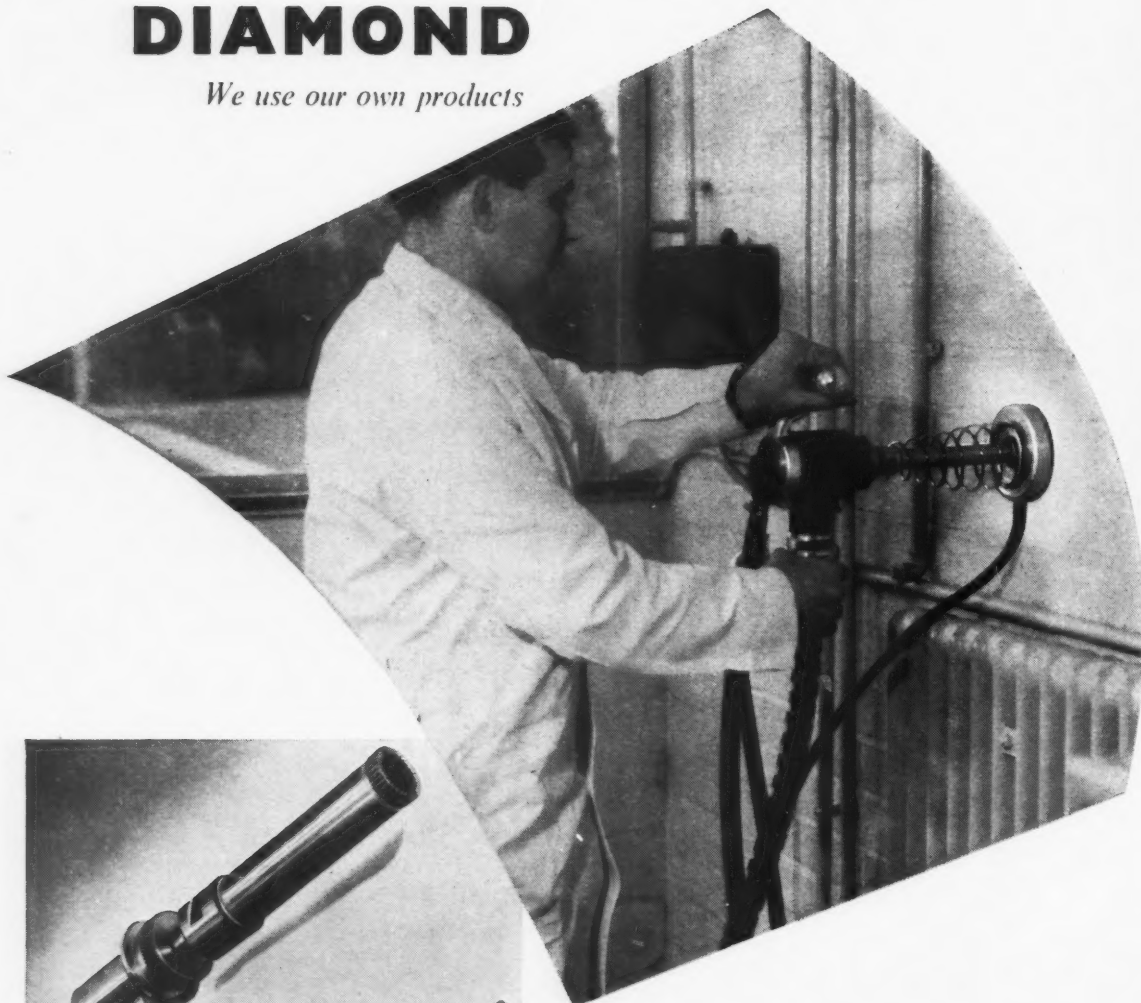
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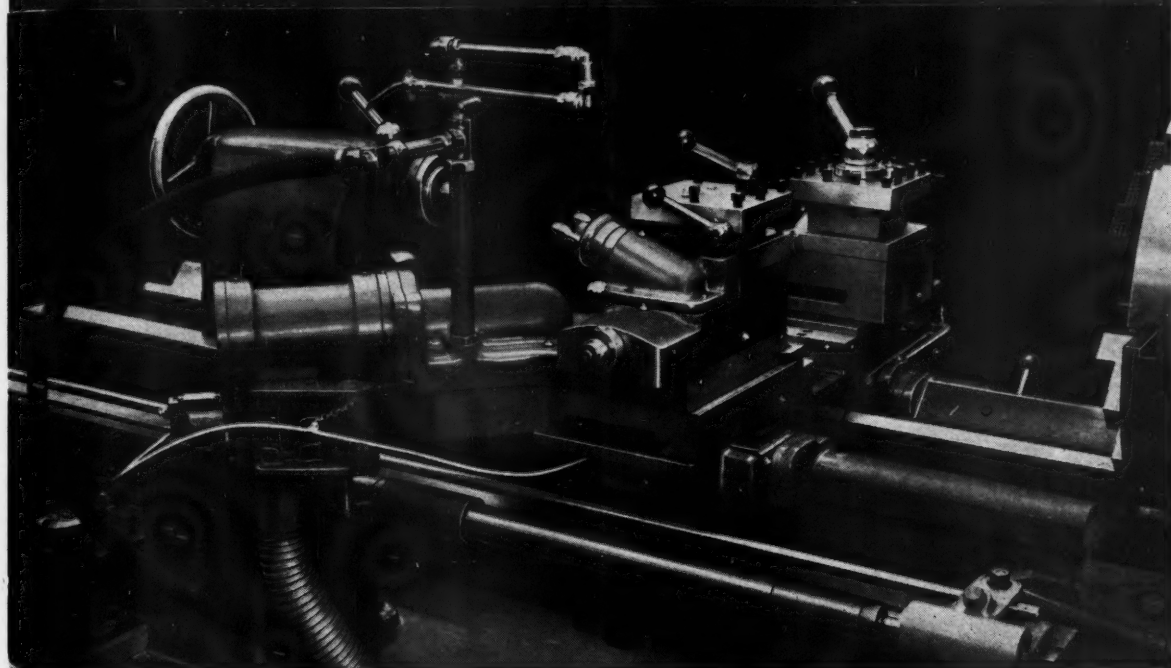
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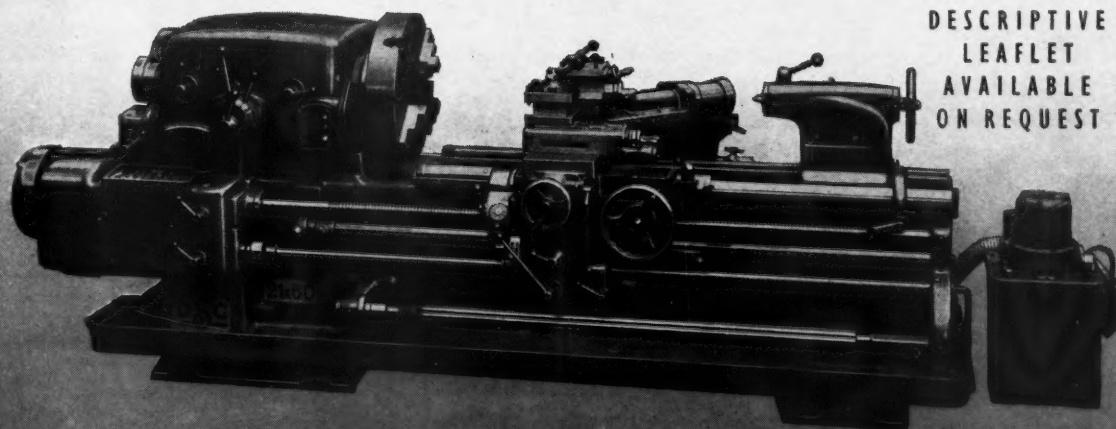
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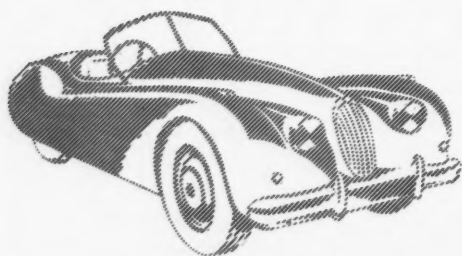


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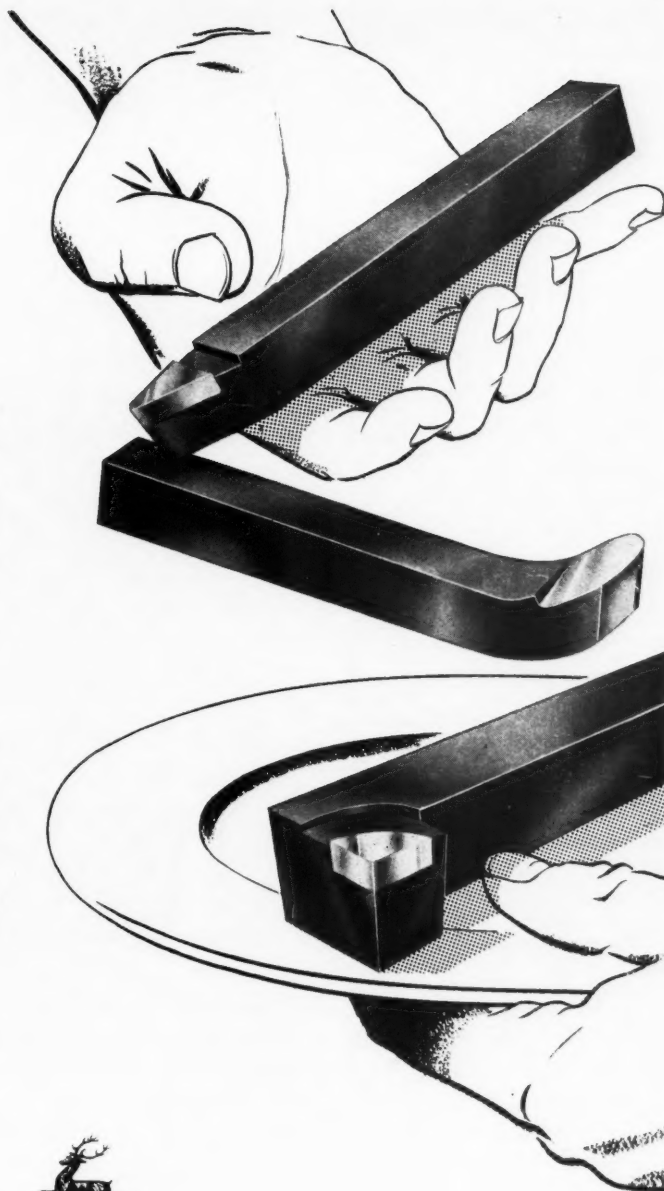
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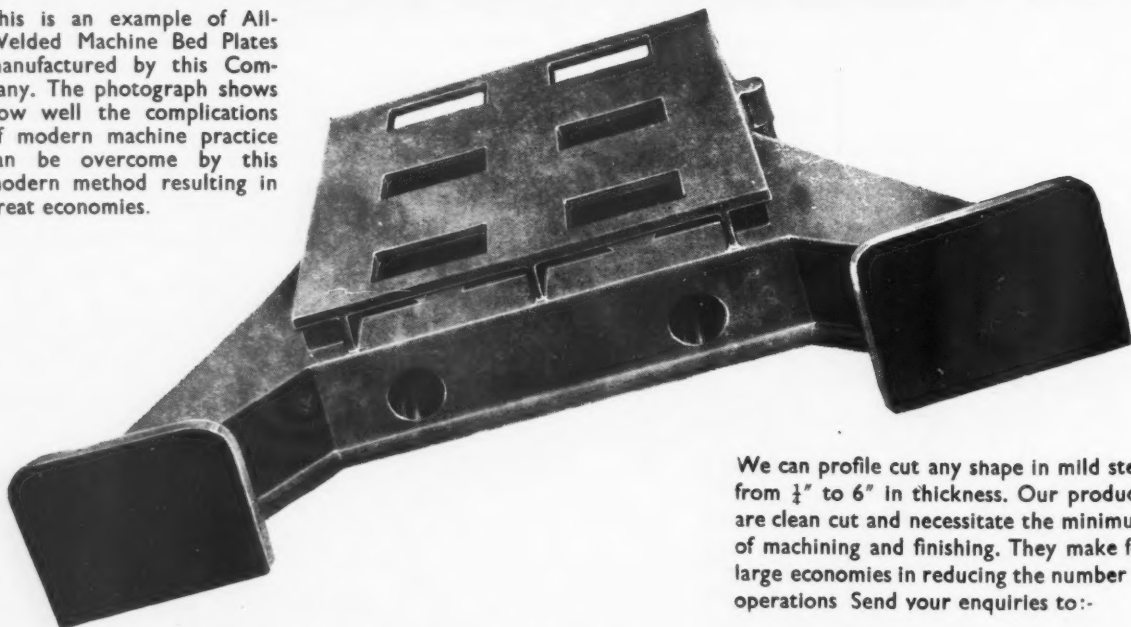
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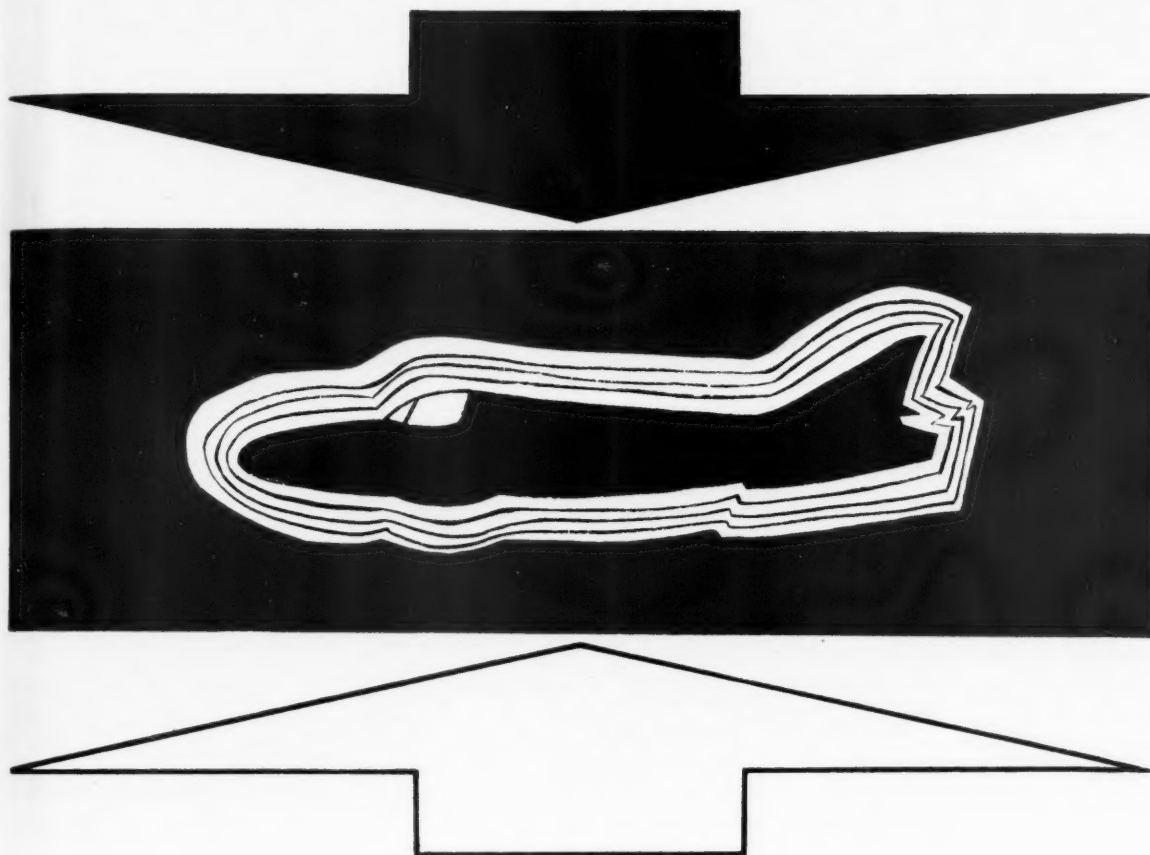
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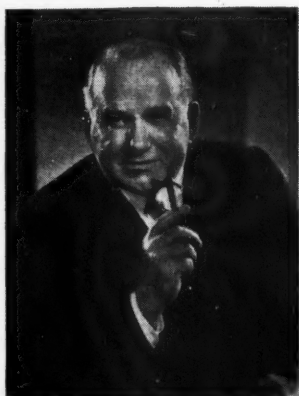


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Technical Education for Production Engineers



by The Rt. Hon. The Lord Hives,
C.H., M.B.E., D.Sc., LL.D.

★ ————— ★

Lord Hives, Chairman of the National Council for Technological Awards, retired as Chairman of Rolls-Royce Limited on 11th January, 1957, after 48 years' service with the Company. During that time, he rose from the position of tester, in a Company which manufactured only motor cars, to the leadership of a great industrial organisation of world renown. In this address, presented to The Institution of Production Engineers at the University of Bristol on 6th February, 1958, as The 1957 Viscount Nuffield Paper, Lord Hives combines some outspoken comment on the subject of technical education for production engineers, with some personal reminiscences of his 50 years in industry.

★ ————— ★

It was not until I started to put this Paper together that I realised the number of definitions which apply to the term "Production Engineer." The definition I have assumed may be yet another one.

It reminds me that when one of the young members of my family went away to school, the letters he wrote home were full of the most terrible spelling mistakes and the way he put words together was very unusual. When I remonstrated with him his reply was: "Well, you know what I mean" and dismissed it at that. So therefore, if you find me describing production engineers in various ways, I am sure you will understand what I mean.

I would like to make it clear that for the past year I have been retired from business completely. I am in that enviable position of having no industrial responsibility. It should also be realised that for 48 years I earned my living with the Rolls-Royce Company, and my observations are inevitably influenced by that experience, but the views I express are my own. When I say "our" and "we," therefore, you will understand what I mean.

Originally it was my intention to talk about technical education, with particular reference to the Dip. Tech. On reflection, however, there have been

so many excellent Papers recently published on this subject that I decided I should give you, first, examples of the problems I have experienced which demanded technically trained personnel.

We must always bear in mind that the training of technicians and technologists is not an educational exercise. There is an end product, and only when that end product is really put to use is it possible to get a true evaluation of the merits of the training. It does not matter how high the qualification; if when it is put to work it does not prove successful, it has not really very much value.

The problems of production

The problems of production start when the first lines of the design are put on paper, so in my definition the designer is a member of the production engineers.

I strongly disagree with the suggestion that is sometimes made that you make an article and develop it and then hand it over to another group of people to "productionise" it. In the case of the particular products I have been connected with, this would lead to disastrous results. It is essential to use all the talent and knowledge available to make certain that the original designs are practical from a production point of view.

It was a rule that the production engineers could not change the design in any detail whatever without the approval of the designer and the chief engineer. It was also laid down that the outside suppliers must get our approval of every change in their design once their product had been approved and accepted. This was found necessary by some unfortunate experiences.

It can be proved that this procedure does not slow up the job in any way. It means that a bit more thought has to be given on the original designs, which will eventually result in a saving of time. I was brought up in a school where there was a maxim hung on notice boards, both in the works and in the offices, which said "THINK BEFORE, NOT AFTER." It is a simple and wise philosophy which is often neglected.

The unity of design, development and production is not achieved by an organisation chart: it has to be built up by confidence in and respect for each partner.

We are all aware of the criticism levelled against designers for the continuous stream of modifications and changes, many of which have been suggested by the production or service departments. I accept that if you are going to keep your product up-to-date and meet the criticisms of your customers, modifications are inevitable. I should feel much more concerned if no changes were being made.

The production staffs have been known to plead that certain pieces were too difficult to manufacture, and they have been so convincing that the designers have accepted their criticism and gone ahead with an alternative design. In some cases it has meant a considerable amount of work, not only in the drawing office but in the manufacture, and in the testing and proving of new design. Eventually it is cleared for production. The works staff then come along and beg to retain the original design. They have over-

come all their troubles in manufacture, and they can promise no savings with the new pieces.

This is no reflection on the production staff. They have been clever enough to find ways of overcoming their original criticism.

You can have similar experiences with the development departments. To overcome certain difficulties they put forward the change in design, but by the time the new design is ready for production, they will have proved by development on the original pieces that the fault has been overcome.

The instances I have mentioned are a small percentage of the total changes, but they have involved the production departments in spending time and effort on a job which is eventually not required.

An exciting job

Perhaps one of the most exciting production jobs during the last War was the manufacture of the Merlin engine in the U.S.A. The production story of this has never been written down. The fact that 55,000 Merlin engines were produced in the U.S.A., the approximate cost of the whole project being \$700,000,000, with a peak production of 100 Merlin engines per day, indicates the magnitude of this job.

Before the end of the War plans were already going ahead for the output of Merlins in the U.S.A. to be doubled by bringing in Continental Motors, which indicates that the project was a success. Although Continental Motors got their factories pretty well equipped, they never made any quantity of deliveries.

It is too long a story to tell you how the Merlin drawings got to America. It was during those exciting days of Beaverbrook at the M.A.P. The first positive information we had was the appearance of one of Beaverbrook's scouts at Derby, with an attache case. He said he had come for the drawings of the Merlin engine, which he was to take to America. He was very surprised when he was informed that the first thing he should do was to arrange for a lorry because about 150,000 to 200,000 drawings and documents were involved!

A popular decision

Although we at Rolls-Royce had nothing to do with the choice of Packard's for this project, we were delighted with the decision. We had a great respect for Packard's engineering ability. Above all, we had great confidence in Colonel Vincent, who was their Chief Engineer and Director. Vincent was largely responsible for the original Liberty engine of the 1914/18 War. He was conscious of the problems involved in producing satisfactory aero-engines.

Packard's were given a direct contract from M.A.P. for 6,000 engines, and an additional contract from the U.S. Government for 3,000 engines. The responsibility of the production, and of the delivery programme was entirely Packard's.

From the start, Packard's made it clear that they had no intention of sending a team over to Derby. There was a production problem and they intended to treat it as such.

An important decision

Rolls-Royce then had an important decision to make. It will be appreciated that at that time we were stretched almost to the limit, but nevertheless the decision was taken to send three of our top executives to Packard. We sent the Deputy Chief Engineer, the Chief of the Development Department, and the Deputy Works Manager. These were people we could not readily spare, but we considered it was essential that decisions should be taken on the spot. When I say that they were people that we could not readily spare, I should add that it would not have been possible to do so but for the policy which had been followed for some time by Rolls-Royce of investing in talent. It would have been no use looking round at that stage for people to take on these jobs. We had to have people already trained and competent to step into the breach made by this team going to America. It was one example of the value of the fact that the building up of technical staff had been going on for a number of years.

You will notice that although this was a production problem, we could not avoid bringing in the designers and the development engineers in addition to the production engineers.

The contract with Packard's was signed in September, 1940, and they undertook to deliver the first complete engine in 12 months. They did in fact produce their first engine in September, 1941. They were not able to cadge or borrow from their neighbours; they were isolated. There was, however, no need for them to do so; they produced their first engine in September, and what is much more important, they were delivering at the rate of 500 engines per month in March, 1942. This was an astonishingly good performance: it exceeded our expectations.

Our team of three arrived in Detroit in August 1940. They were immediately involved in advising Packard's on some very important decisions. Obviously the first thing was to arrive at a specification for the engine.

It had been rather lightly assumed that the engine for the U.S. Government would be identical with that produced for the British Government. This was soon found to be impossible. The British engine had to be interchangeable installationally with those made in this country. A number of the engines from the United States were for delivery to Canada to be fitted in the Hurricane, Mosquito and Lancaster aircraft which were being built there.

When Packard's examined the Merlin drawings they had received, it was at once noticed that the arrangement drawings had first angle projection, which was the British standard, whereas the standard in the U.S.A. is third angle projection. Packard's decided that it would lead to too much confusion to put drawings with first angle projection in their factory, so about 2,000 to 3,000 drawings had to be re-drawn. This was very unfortunate, because it was not anticipated when Packard's gave their first promise of delivery.

I intend later on to refer to the difference in the British and U.S. standards for drawings.

Allocating responsibility

Soon after the three Rolls-Royce engineers arrived at Packard's, a meeting was held to decide the policy in connection with this project. It was again emphasised that the responsibility for the specification, the manufacture and the promises for delivery rested with the Packard Company. The fact that the members of Rolls-Royce were in their factory did not in any way relieve them of that responsibility.

It was also made clear that the designs which were handed over to them were for a well tested and proved engine, but if Packard's chose to make alterations it would be their own responsibility, but they would at all times have the benefit of Rolls-Royce advice and help. We found that this freedom had a great restraining influence on Packard's and they did not lightheartedly embark on changes to the design. If it had been laid down that no changes were to be made without the approval of Rolls-Royce I am sure that we should have had an internal battle the whole time. It is a policy which we have adopted in other cases. We never put ourselves forward as having all the knowledge; we say, "This is the result of blood, sweat and tears on our part, but if you know a better way of doing it we should like to hear about it from you."

The project started with some inherent advantages; for instance (1) the dimensions on the drawings were expressed in inches and decimals, which was U.S. standard; (2) the direction of rotation of the airscrew was the American standard, although the Merlin was not the British standard which was a bit of luck; (3) on the outbreak of war we organised a small mission in the U.S.A., with experts, to purchase material and parts for the British production. So we had considerable knowledge of the equivalent materials which were available.

We received hundreds of crankshaft forgings from Wyman-Gordon in the U.S.A. which were built into British engines. We also purchased other materials, and especially ball and roller bearings. Thousands of these were imported for British production.

Use of American accessories

The next decision was that the engines produced by Packard's, both for British and U.S. contracts, would use American accessories as far as possible. We found that there was no suitable magneto being produced in the U.S.A. and therefore arrangements were made with Delco to produce in that country the B.T.H. 12-cylinder magneto for the Merlin, to British standards. At a later date they developed their own magnetos. I enjoy recalling these things, because we used to do things quickly in those days. Now, I am afraid, when I look at some of these figures I wonder whether I am telling the truth, but the facts support me.

We decided on the Bendix carburetter for both British and U.S. engines, also the American starter

motors, generators and fuel pumps. It had to be accepted that the propeller shaft serrations were different on the two marks of engines: we stuck to the British standard on British engines, and the U.S. engines were made to the American standard. This destroyed the installation interchangeability of the complete engines.

As the project progressed, and after many thousands of engines had been built, other changes were introduced. One of the principal ones was that when Packard's changed over from the 2-speed, single stage supercharger to the 2-speed, 2-stage supercharger with intercooler, they embodied supercharger drive gear of their own design.

We kept in very close contact the whole time. They were always aware of our troubles and problems; we never pretended that we did not have any. In the early stages we had trouble with the Rolls-Royce design of the 2-speed gear, which was eventually overcome by development, but in the meantime Packard's had made and improved their own gear which went into the same space and therefore they continued with the Packard gear. In service, both types of gear operated satisfactorily.

An important issue

The most important issue was the question of screw threads. The design of the Merlin engine, where the maximum use was made of aluminium castings, meant that there was a large number of studs used and the essential studs, like cylinder holding-down studs and bearing cap studs, were considered a permanent part of the construction. Considerable development had gone into arriving at the right interference fits and dimensions. The decision was finally taken that Packard's would use the Rolls-Royce standard threads, identical to those in service on the British Merlin engine. I always think that this was one of the outstanding events of the War, to secure the adoption of British threads. They tended to adopt the attitude "Anything that you can do, we can do better," but this adoption of British threads affected not only Packard's, but a multitude of outside suppliers, who had to get accustomed to these foreign threads, and no one would listen to the suggestion that this should make any difference with regard to delivery.

The other important decision was that they would retain the Rolls-Royce standard hexagons, so that the spanners and tool kits were standard with the British design.

This changeover to Rolls-Royce threads was not achieved without a lot of grief and pain, and tremendous credit is due to the Packard organisation for carrying it through successfully. Many firms in this country who have recently changed over to the uniform threads will be able to appreciate what it means.

In arriving at the specification for the engine, Packards were anxious not to embark on an out-of-date specification. There were a number of new improvements which had been type-tested and proved for production at Derby, but had not got on to the production engines which were being delivered. The big item was an entirely new design of cylinder

block with 2-piece construction. The decision was taken that this would be standard on all Packard-built engines.

There were several other smaller items which came into the same category, but Packard's had to exercise considerable judgment because nobody would accept that their delivery dates which they had promised could be extended.

There is no doubt the wisdom of sending first-class people helped very considerably, because the decisions had to be taken in the U.S.A. We made it very clear from the start that we did not expect their problems to be referred to Derby. This did not prevent streams of queries coming from our people out there. Over the whole project there were difficulties galore, but they were all resolved between the Rolls-Royce and Packard organisations, and there was never any question at any time of outside people being called in to arbitrate.

Although Packard's made use of their existing motor car factory they had to build several extensions, and the big undertaking was the equipping of engine test beds and brakes.

Although for some time previous to the War Packard's had practically dropped out of the aero-engine business, they had in the past produced their own aero-engines, and therefore they had a very capable engineering staff with a full knowledge of the problems.

They had to obtain and install 3,700 new machine tools. Very little of their old motor car plant was used. They had the usual delays on deliveries, but at that time they were getting better service from their machine tool suppliers and they would not accept delivery of machine tools unless they were fully equipped. That may remind us of the large numbers of machine tools over here, which took a long time before we could get them to work.

When you went round their factory, even though they were up to their peak of 100 engines a day, there were no startling innovations or methods compared with, say, Ford's, of Manchester, or Rolls-Royce, Glasgow. They used more multi-spindles on their drilling and boring, and they made more use of vapour blast and tumbling for deburring. They taught us a good deal about the extent to which tumbling and vapour blasting could be used. As you would expect, all hand work was reduced to a minimum.

A great encouragement

What gave everybody a lot of encouragement was that the first engine which was sent to Wright Field for type test went through with no difficulties, and finished giving the same power as on the first run. Wright Field was known as the graveyard for many engines, and the result was a great encouragement for us.

The U.S. Air Force although they ordered 3,000 engines from Packard's, were not very excited about the merits of the Merlin. The first of their deliveries were installed in the Curtiss P.40, which was not a very modern aeroplane. It was only after the Merlin was

installed in the P.51—the Mustang—that the U.S. Air Force placed the Merlin as one of the highest priorities in the U.S.A., and the decision to create the additional production at Continental Motors was to meet the U.S. Army Air Force demand.

We got a great deal of satisfaction out of this, because it must not be thought that the people out there stood with open arms to welcome the foreigners. At that time the engine had to sell itself. It is very nice, when reading United States history, to find that they attribute the real changing-point in the whole procedure to the time when the Mustangs could escort the day bombers as far as Berlin. It is a source of great satisfaction to us that these machines had Merlin engines.

Provision of spares

On the question of spares, tools, instruction books and repair manuals for the Packard engines, the U.S. Army Air Force insisted that these should be delivered with the production engines, and, as they were not very excited about the engine at that time, we had no get-out. You can imagine that this was a big undertaking because Packard's, having no experience of the engine, had to rely on Rolls-Royce for their first spares schedules. Because of the fact that the Merlin was a non-standard engine in the U.S. Air Force, it was essential that adequate spares should be available.

On the whole, the spares supply was up to schedule, but this did not mean that there were not occasional serious shortages.

Considering the Packard job in retrospect and the potential possibilities of the hazards and difficulties, this project went through remarkably smoothly. There were difficulties galore, and differences of opinion which had to be resolved, but there was never an occasion when we had to call in anyone from outside to arbitrate. The difficulties were all overcome inside the Packard and Rolls-Royce organisations.

The nice thing about it is that we made some very good friends, not only at Packard but in the U.S. Army Air Force, and there was a mutual respect for each other's capabilities. *We demonstrated that an essentially English design could be produced successfully in the U.S.A. in quantities, and it is a nice thing to have that on record as something achieved.*

In addition to the manufacture of Merlin engines in the Rolls-Royce factories at Derby, Crewe and Glasgow, Ford's of Dagenham undertook to produce Merlins at a factory in Manchester.

Ford's had the problem not only of producing engines, but also of building and equipping a new factory. In this case the Ford personnel, whilst waiting for the completion of the factory, were housed at Derby, and at one time there were approximately 100 people working on this project.

Again, the same policy was adopted. Ford's received direct contracts from the Government, and they were completely responsible for the production schedules and delivery promises. It was also agreed that they should create their own alternative sources of supply and not depend on those supplying Rolls-Royce.

Their programme called for the supply of the 2-speed, single-stage engines: they never changed over to the 2-stage engine.

Up to the end of 1945 they had delivered approximately 30,000 engines. In the latter half of 1944 they were consistently producing 900 engines a month.

There was never any question about the quality of the engines produced by Ford's: they were equal to any of those produced by Rolls-Royce. They were accepted as another Rolls-Royce engine and were serviced by Rolls-Royce mechanics.

Gas turbines

In 1947 Pratt & Whitney took a Licence to produce the Rolls-Royce Nene jet engine. This engine was based on the original Whittle design with the centrifugal compressor. The engine was known in America as the J.42.

Their interest in this engine was aroused when the Nene completed one of the first—if not the first—successful model tests of a jet engine in the U.S.A., at the Naval Establishment at Philadelphia. Pratt & Whitney received a contract from the U.S. Navy for the production of this engine.

As soon as the drawings were received at Pratt & Whitney they were in the same difficulty as Packard's, due to the fact that the drawings were first angle projection and their standard was third angle projection. Therefore all the major drawings had to be redrawn.

Pratt & Whitney made the engine to the R.R. design; they used the R.R. standard screw threads and hexagons; they also used the Lucas fuel system which was standard on the Rolls-Royce engines, and they placed a contract direct with Messrs. Lucas.

Pratt & Whitney sent only a few people to Derby on the production side, but it was arranged that there was a permanent Pratt & Whitney office in the Derby factory which handled all their queries.

Over a thousand of these engines were delivered to the U.S. Navy and gave very good service.

A more powerful engine

This engine was followed by a more powerful engine of a similar design, known here as the Tay, but the development on this engine was dropped at Rolls-Royce in favour of the Avon. It was therefore left for Pratt & Whitney to develop this engine, which they did very successfully, and delivered over 4,000 engines. It was in production at Pratt & Whitney until comparatively recently and was known as the J.48. On this engine they changed over to Pratt & Whitney standards.

In 1953 Westinghouse took a Licence for Rolls-Royce axial jet engines. This agreement is still in operation.

It will be seen that Rolls-Royce have acquired considerable experience in working with U.S.A. industrial firms. We enjoy working with them and

there is no doubt it has been to the benefit of both parties.

We spent a good deal of time over there. I sometimes envied them their facilities so far as equipment is concerned. They have much more ample equipment. I used to console myself with the thought that, when we were developing the Merlin, every engine maker we visited would show us high altitude test equipment for his engine until we felt that we were near to screaming; but, when it came to operation, by far the best high altitude engine was the Merlin, which had never been in a high altitude test stand. If you have little equipment you have to give more thought and time to understanding your problem, whereas if you have a great deal of equipment it is tempting to say, "Have a go, Joe, and see what happens." That is something to bear in mind. You must keep your facilities under control and make sure that you do not spend most of your time looking after the facilities instead of doing the main operation.

Continental projects

In addition to our efforts in the U.S.A., Hispano in France; Fabrique Nationale in Liège, Belgium; and Flygmotor in Sweden are still manufacturing Rolls-Royce engines under licence.

Hispano commenced immediately their factory was handed back. They operated under very severe handicaps for some time and they were dependent on supplies and parts from this country and therefore the engines were to the British design. As soon as conditions became more normal and they had completed the re-equipment of their factory and built test facilities, they rapidly produced engines which were supplied to the French Air Force. Later there was a demand for metric dimensions. We stated that we could not undertake this work and they would have to do it themselves and take the responsibility. A compromise was that all the dimensions on the R.R. drawings were translated into metric by using a factor and accepting an odd metric dimension.

This meant that the parts were interchangeable with the British, although in metric dimensions. Later the French Air Force insisted on metric spanner sizes and therefore the dimensions of the nuts were different from the British.

Hispano also produced a more powerful engine similar to the Tay. On this engine they have done their own development. This engine is known as the VERDUN in France: it has given very good results, and is still being produced by Hispano.

In Belgium, the F.N. Company at Liège have made and delivered approximately 1,000 Derwent engines. They are now producing Avons. There again they used our dimensions, but they are metric on the drawings.

Flygmotor in Sweden work to Rolls-Royce designs with the dimensions shown in metric. An exception is the screw threads and nuts, where the sizes are quoted on their drawings in British dimensions.

It is interesting to consider what we have learned from working in close contact with the various firms. One thing we have learned is that the quality of workmanship is not a monopoly of any one country. Providing the desire is there, the results can be and have been achieved.

What I wish to emphasise throughout is that we could not have undertaken all these projects but for the fact that for some time previously we had been building up our technical staff. However good graduates may be, it is five or six years before they can carry very much load. In providing military equipment, part of our responsibility was to anticipate how we should deal with an expansion. When we ran our works at places such as Crewe and Glasgow, we had some wonderful people coming in to help us. I do not think that they ever received the recognition that they deserved, because they gave up permanent, stable jobs to come in, and they made a wonderful contribution.

Use of the metric system

In working with the Continental firms you find that they are firmly committed to the metric dimensions, and although they have accepted the compromise of converting the British dimensions to metric we have noticed no desire for them to change over.

When we hear of Russia, China, India and Japan adopting metric dimensions, the inch measurement is losing ground. If and when the European Market is a fact, it is going to be increasingly difficult for this country to be the only one in Europe not using metric dimensions as engineering measurements.

Personally I am a supporter of the inch, which can be divided by a thousand, as the right dimension for modern engineering. This is a matter of great interest to production engineers. I should like to find out who was responsible for uniform threads. This is obviously a production question and for you to decide, but I think that the uniform thread was "wished on us" without sufficient thought, and we were rather overawed by the Americans. I can see that even before we have digested uniform threads you are going to have the metric system pressed on you, and you had better have your answers ready, because the position is going to be very difficult. We used to look on metric dimensions as funny dimensions that the French used, but we now have Russia, China and India changing over. The writing is on the wall. I believe that the British Medical Association are thinking of changing over to metric weights. It is very logical to go to grammes instead of grains. As I was coming to Bristol to-day, I wondered what production engineers would do if given the job of changing over to metric dimensions. You know how deep it goes, very much deeper than we used to believe. You may have it wished on you, because it is very difficult to visualise this country going into the European Common Market as the only one not using metric measurements.

Third angle projection

Another point which I think should be resolved is the projection to be used on drawings. I might tell you that owing to the Rolls-Royce unfortunate experience in the U.S.A., they have changed over completely on the aero division, motor car division, oil engine division, and all jigs and tools, to the third angle projection. Although we were concerned about the difficulties and problems, we found that once the decision was made the difficulties diminished. It is unfortunate, however, that students and graduates are taught first angle projection.

We found that a good deal of publicity was given to the Rolls-Royce drawings having to be redrawn. Pratt & Whitney came out with the same story. The implication was that the design was no good, and it was very difficult to impress on the uninitiated that it really made no difference. People said, "You are crazy. Why don't you make up your minds which way you want to do it?" I think that this Institution ought to have some influence. There is the problem of how to dimension the drawings. That is the sort of thing which could go on for ever, so that I think that you ought to take the first step. The B.S.I. are non-committal and say that we can have either.

Another problem is the direction of rotation of engines. The Merlin is not to the British standard, but we promised after that to be good in future, and therefore the Griffon is to the British standard. Merlins had been operated off small carriers, and the torque of the Merlin carried them away from the tower, but with the latest engines the torque of the propeller carried them into the tower, which was disconcerting. We have had them going both ways, and I feel that this question ought to be settled. It is unfortunate that when we come to the turbo-prop we are still out of step.

Where this hits us is in regard to test equipment, because test equipment is a very expensive item, and it is not just a question of putting something round the other way. I do not know of any justification for the continuance of this difficulty.

Costs

We attempted to make a comparison of the costs of production in the various factories. We had an excellent opportunity—identical Rolls-Royce pieces were being made, in many cases on identical machines.

It was soon apparent that to make an accurate comparison which meant anything was going to absorb some of our best talent, which in the middle of a war was not justified. We did, however, reduce it to one identical item being machined on similar equipment. In one case the operator was paid piecework bonus, and in the other the operator was on a flat rate. We took it over a fairly long period, but there was no worthwhile difference.

At the height of the Merlin production in this country there were various types of payment. Derby was working on the premium bonus system and still is; Crewe and Glasgow were on piecework bonus, and Ford's on a flat rate.

Sometimes it would be shown that there was a wide variation in the costs in the various factories, but on investigation it was usually found to be a clerical error, or the management was to blame.

My experience has taught me that if you are not satisfied with the efficiency of the factory, investigate the management; if it is still wrong, investigate the management again, and only after that can you tackle the man on the shop floor. By management, I include everyone except the operator. My experience is that provided the men are not frustrated, and that the tools are there and the material is there and so on, you can get the output that you want from them.

My impression of production in the U.S.A., was that I admired their scheduling and their material control. They appear to pick up the faults quicker than we do, and they could anticipate far enough ahead the shortages of material or tools. The programme was on a daily output; in fact the original facilities were based on producing three Merlins an hour.

All the American suppliers were conscious of what was expected of them and their deliveries were timed to meet the programme.

In order to complete the picture of the number of industrial organisations which have produced Rolls-Royce engines, I should mention that the Bristol Aeroplane Company, the Standard Motor Company, and the English Electric Company each manufactured a number of Avons. Although the batches were relatively small, they provided the usual number of headaches which we expect when starting up a project in a new factory.

I must not overlook the effort of the Commonwealth Aircraft Company in Australia. They manufactured successfully a number of Nene jet engines for installation in Vampires built in Australia; and later changed over to Avons, which they are making for installation in the U.S. Sabre aircraft built in Australia for the Australian Air Force.

Australia are capable and efficient producers. The handicap they have, of course, is that their orders are for very small numbers.

Technical education

I would like to give you my personal views on this much-discussed subject of technical education for industry. It is necessary to give you a bit of my background history because it will help you to judge the value of my remarks.

Over 30 years ago, as soon as I had established myself in a position of responsibility, I realised my own shortcomings and that it was essential that I should engage as some of my assistants men who had been trained in a university. Twenty-five to thirty years ago there was no question of waiting in a queue to engage graduates: their anxiety was whether they were going to get jobs at all, and therefore you received many applications.

It is an interesting fact that the graduates who were engaged by me 25 to 30 years ago are now at the head of Rolls-Royce. They fill the following posts—

Technical Director of the Rolls-Royce Company; The Managing Director, the Chief Engineer, and the General Manager of the Motor Car Division; The Managing Director of the Oil Engine Division; and the Assistant Chief Engineer of the Aero Division.

It is of interest to mention here that three of those men came from Bristol University, so that we are very grateful to this University. The Chief Executive of the whole Rolls-Royce group, although I did not engage him, was for many years on my staff. He was technically trained.

I have avoided names because there are so many others in key positions, or who have left to take better positions elsewhere.

On reflection, I do not think I would claim that as graduates these men were outstandingly brilliant. I attribute their success firstly to the policy of the Company which was to invest in talent, but perhaps what contributed even more was the *environment* in which they developed. That is the most important factor of all. They had the opportunity to rise, and the fact of outstanding importance was that the conditions in the company were of the right kind for them to do so. At the time when they came to it, Rolls-Royce was a relatively small company, manufacturing one type of motor car and doing very little aero work. We were the best customer of the universities at that time and I remind them of that occasionally, when we are asked to wait in a queue!

A creative genius

We were all influenced by the creative genius of the Company—the late Sir Henry Royce. He was a great believer in doing your development work on the drawing board. I support that wholeheartedly. What was his chief quality? I think that it was his infinite patience and attention to detail. When a design was completed he had satisfied himself about all the features of it, including the stresses and so on, and therefore, if it did not turn out right, the first question that he asked was, "Where was our thinking wrong?" It was not a question of "Well, Joe, make it a bit thicker," but of "Where did we go wrong?" It was a great education, and it meant that he would sit patiently at the drawing board, having another go. One result of this is that there are many pieces in Rolls-Royce designed over forty years ago, and the reason that they are still there is that no one has found a way of making them better. It followed that our best engineers were all designers and worked on the drawing board.

On the education side, I organised a kind of survey. I said, "Which way have these people come up? Is there any one channel which produces the best results?" The result showed that there is not any one channel, and I do not think that that is very surprising, taking into account the difference in the standard of intelligence of individuals and the wide range of jobs to be filled in an industrial organisation.

Shortage of creative designers

At the present time I do not believe that there is a chronic shortage of scientists; the chronic shortage is in creative designers. The first qualification for

this post is experience: technical qualifications are not, in themselves, sufficient. It is essential that they should have had considerable drawing office experience, and also practical training. They must be able to work with specialists.

The usual university graduate does not take kindly to drawing office work; he looks for a more glamorous career in research, development and testing. Industry is largely responsible; there is not sufficient encouragement given to first-class designers. I think that this is a very important point. We know that there are some firms, who have made a success of it, who really work with project engineers and draughtsmen, and there is all the difference in the world between a draughtsman and a designer. My experience is that there is need for men of the very best quality on the drawing board, and they make sure that things are right; because that is the time to change one's mind and make alterations. The expense piles up afterwards, when you find that you are committed. You may feel that it should be possible to have a better design, but you are then so far down the road that you cannot turn back.

The backbone of most design staffs are men who have served an apprenticeship, with part-time and evening classes at a technical college and who have taken their O.N.C. or H.N.C. A number of these men turn out to be brilliant.

With regard to the "new look" in education, I am convinced that so far as production is concerned the university is not the right environment for production engineering. If there is one thing which fits into a sandwich course I think that it is production engineering. We have had the experience that the universities cannot keep up to date in production engineering, and therefore I am always doubtful about a production engineering course in a university.

Rolls-Royce have decided to have a "thick sandwich" scheme sponsored by the firm. A man who is sponsored by the firm will do a year with them and then his three years academic work, and then come back to the firm for a year. I believe that that is better than three years at the university followed by two years training with the firm. The average student should have an opportunity to look inside a factory before he starts on his career.

Coming to the Dip. Tech., I want to emphasise that it must never be thought that the Dip. Tech. is in competition with or replaces any of the other awards. Such an idea is quite wrong. It will be quite a long time before the Dip. Tech. has enough students going through really to prove and establish its value.

I believe in the Dip. Tech. as a means of increasing the supply of qualified technologists. What I expect from it is that it will spread the net wider and gather in some brilliant people who at present are not going to the universities.

I have had the experience of one of our bright apprentices who was qualified to take up a place in a university. He was anxious to know what job he would be given when he had completed the course. The only answer was that there could be no guarantee

given as regards what the job would be, but we could promise that there would be a job for him, and the fact that he would be much more qualified should open up better possibilities. His answer was that he was learning all the time in the factory, and that would have to be debited against the knowledge he acquired at the university. This young man had a definite ambition and he was convinced he would finish with better prospects if he stayed on his present job and carried on his studies at the technical college.

I think his real difficulty was that he was enthusiastic and happy and could see the prospects of advancement, and did not want to break his employment with the firm.

There are others who for family reasons do not wish to leave home. Amongst these people there is a fund of talent which should be given every encouragement.

Spreading the net

We are all aware that the number of people who are capable of absorbing higher technical knowledge is relatively few, and therefore the desire should be for the net to be spread as widely as possible to gather in all those who have that potential. The Dip. Tech. should help to do this.

In most cases the student will be sponsored by a firm, and the fact that he knows he is returning every six months gives him the satisfaction of continuity and that he is not going to be forgotten.

In spite of the satisfactory start of students entering the Dip. Tech. courses, its success has still to be proved in practice.

In the foreseeable future the amount of sheer knowledge the technologist must have will steadily increase. Much more will be demanded of educational facilities. The time of learning ought to be more prolonged. Not only so, but its *quality* must be maintained and raised.

This is the object of the setting up of the National Council of Technological Awards—to guarantee and safeguard the *quality* of the Dip. Tech. and any higher Diploma that may be introduced.

Our work is not to find the bodies—that is your responsibility—nor to create new ways of technical education—that is the task of the colleges.

All the same, you cannot ensure the quality of the qualification without overseeing what the educational authorities provide. The Council, in fact, finds the standard of equipment, libraries, buildings, etc., low compared with those of countries overseas. Also there is a general lack of student amenities—playing fields, common rooms, study facilities and the like. Nor are members of the teaching staff as highly qualified as they ought to be. There are exceptions, of course.

Support from industry

Some technical colleges complain that they find little support from industry and that many firms are apathetic. This ought not to be. On the other hand, I know of colleges where an industrialist has never been appointed to the Governing Body. They are “closed shops.” Industry should strive with

might and main to get this altered, for it may be that every course held by the college is for some industry.

The work of the Council in setting a high and independent standard is bearing fruit in encouraging improvement. The Dip. Tech. scheme, under the charge of an independent body, means complete freedom from traditional methods. It should raise the standard of the technical colleges, and those who take the O.N.C. and the H.N.C. should benefit from that improvement. The Council works closely with industry and comprises a goodly number of industrial heads. Sir Walter Puckey, a past President of your Institution, is one most welcome to us. Our deliberations are greatly assisted by the expert knowledge of factory organisation that he and others bring to our Council Board. It will ensure that our technical colleges develop on their own lines, different no doubt from the Continental but no less efficient. Eventually they will take a greater and nobler share in our industrial and commercial life.

The fact, which is now realised and accepted, that this country has slipped behind on technical education must be attributed to the neglect over the last 10 to 15 years. We cannot criticise our system of education before that, because we could never have built up the British Empire except that our universities turned out large numbers of first-class men capable and qualified to take over the responsibility of administration, etc. A classical degree in History or Law was excellent training for this purpose.

We can all remember the hundreds of men who left this country and joined the Indian Civil Service or the Indian Army, and in addition large numbers went to other parts of the Empire. They did a magnificent job and laid the foundations for bringing about the self-government which many of these countries now enjoy.

When a country takes over self-government, its first desire is to be independent of foreign administration. If we anticipate the future, this process will be extended.

An urgent problem

We can have confidence that the universities will catch up with the changed world conditions, but it has got to be tackled with a sense of urgency. In my opinion they still suffer from a lot of built-in drag from some of the classical professors.

The time is past for discussing the merits of a classical or scientific or technological education. Applied science is a part of our life. It is in our homes and in everything we eat or wear, and above all, we enjoy it.

To meet the demand for more technically trained people, we shall not have achieved anything if we do this by lowering the standards. It is necessary for the best brains and the brilliant scholars to take up a technical career if we expect to maintain the present standard of living in this country.

One of the criticisms levelled against technical education is that it is too narrow and that the syllabus should include more liberal studies. This criticism has been accepted: there is general agreement that it would be nice for time to be allowed for more

liberal studies. The difficult decision is, what shall be given up on the technical side to allow for this?

It has been stated that the reason a large number of industrial firms have non-technical people at their head is because the technical people have not a broad enough outlook. I do not subscribe to this. I put forward as one reason for this that the technically trained people are so valuable and so precious that they cannot be spared to undertake non-technical jobs where other people are available. This will correct itself, as we increase the number of technically trained men.

I am one of those people who do not believe there will ever be another major war. The reason for this is that the scientists have made it not worthwhile—not the politicians.

Russian competition

What I am concerned with is the competition we can anticipate in the industrial markets of the world from Russia. The writing is already on the wall. When the challenge becomes serious it is the British industries which will have to face it, and if the quality and prices of our products are not competitive, we shall be out of business. No Summit Conferences can put that right.

The recent successes of the Russian scientists and technologists are not due to accident or a bit of luck. It is the result of planned policy over the last 25 years. I do not believe that we have the answer to this.

For instance, in Russia the Professors or Teachers in their technical colleges are the highest paid people in the Government. Their salaries are higher than the leaders of industry and also their social standing is on the highest level. Are we prepared to face up to this?

I know some people in universities who, although they give lip service to the necessity of scientific and technical education, do not really believe in it. They

look upon science and technology as an upstart which disturbs the peace and tranquillity they have been accustomed to.

On the social side, we have still not completely accepted that commerce and industry is something the best people should be connected with. One is considered far higher up the social scale if one's picture appears in one of the society journals, than if one is the person who has written a thesis on a technical discovery which eventually everyone enjoys.

I shall not consider that we are serious in our endeavours to produce more scientists and technicians until the universities and the technical colleges work much more closely together.

Finally, in whichever direction we look we find ourselves short of knowledge. When a mistake is made, or we fall behind technically, it can usually be attributed to lack of knowledge.

We cannot expect to compete with the U.S.A. and Russia in numbers, but we must do everything possible to compete in quality.

A mean outlook

The country still has a mean outlook on education. Most of the capital expenditure now agreed should be debited to our past neglect. £100,000,000 for the colleges may look very nice, but it is only £10,000,000 a year over the last 10 years, to make up for the neglect during those years.

I should like to thank your Institution for inviting me to present the Nuffield Paper. I treat this as a great compliment. I apologise for it being a disjointed effort; I anticipated that in declaring the title. I wish that all the members of your Institution may get as much joy and pleasure out of their working life as I have done.

REPORT AND DISCUSSION

Chairman :

Mr. G. R. PRYOR, M.I.Prod.E.,

Vice-President of the Institution.

THE Chairman said that on behalf of the Institution it was his pleasure and privilege to welcome all those present in the delightful lecture theatre placed at their disposal by the University of Bristol, and at the same time to thank Sir Philip Morris, the Vice-Chancellor, for making this accommodation available and to congratulate Mr. R. W. Hancock and his Committee of the Western Region on having sufficient influence to make this possible.

They had met to listen to the fifth Viscount Nuffield Paper, a Paper which had been established by the Institution to honour the name of Lord Nuffield, who had been its President from 1937 to 1939, and whose generosity had enabled it to found its Research Department at Loughborough College, which had now developed into the Production Engineering Research Association of Great Britain.

Lord Hives, who was to give the Paper, needed no introduction to his present audience. It was particularly fitting that they should honour him by asking him to give the Paper and that he should honour them by accepting the invitation, because he too, like Lord Nuffield, was a most distinguished engineer and administrator. When Lord Hives retired from the Chairmanship of Rolls-Royce about a year ago, after 48 years' service with that Company, he had brought it into a position in world-wide engineering which would have astonished and delighted those founders of whom he was such a devoted disciple in his early years. Indeed, he had achieved something which, the Chairman believed, no other man had achieved, because he had brought the name of his Company into use not only in Britain, but over the whole world as an adjective in the English language which was applied colloquially to any product which was of the highest possible quality and the best of its class. For this reason the first part of his Paper, which was largely devoted to reminiscences of his time at Rolls-Royce, was of enthralling interest.

The second part of his Paper was concerned with technical education. Education had always been one of the main planks in the Institution's platform. The

Education Committee of the Institution had just completed the major task of redrafting the examinations and establishing new syllabuses to meet the changing needs of industry and the Institution's policy of "broadening the base". This part of the Paper, therefore, would be of special interest to them.

There was another link which made the presence of Lord Hives particularly happy. Another Past President of the Institution, Sir Walter Puckey — whose absence that evening, due to illness, was deeply regretted — served under Lord Hives' Chairmanship on the governing body of the National Council for Technological Awards, and was Chairman of its Board of Studies in Engineering.

They were present to listen to Lord Hives, and the Chairman had much pleasure in asking him to present his Paper.

(Lord Hives then gave the address

which appears on pages 207 - 216.)

Sir Roy Fedden, M.B.E., D.Sc., Hon.F.R.Ae.S., who was invited by the Chairman to open the discussion, thanked Lord Hives for his singular contribution that evening to the all-important question of training production engineers, and said that those who had had the privilege of knowing Lord Hives throughout his distinguished career in industry were delighted to see that, now that he had relinquished the helm to other hands, he was devoting his inspiration and energy to the vast subject of technical education.

He hoped that Lord Hives was right about there not being a Third World War. Sir Roy agreed with him that if we allowed ourselves to be outdistanced by Russia on engineering matters, and the rest of the world discovered that we could offer less than Russia could, the remainder would, in due course, tend more and more to fall under Russia's influence.



Personalities at the reception preceding the meeting at the University of Bristol: 1. Lord Hives (left) chats with Professor J. L. M. Morrison, Engineering Faculty, University of Bristol; and Mr. H. G. Gregory, Chairman of Council (centre). 2. Mr. S. Brook (right), Secretary of the Regional Council for Further Education for the South-West; with Mr. J. L. Kimber, of J. S. Fry & Sons Ltd. 3. Sir Philip Morris, Vice-Chancellor (right); with Mr. W. U. Snell, Past Chairman of the Western Section; and Mr. Frank Lister, Director, R. & A. Lister Ltd. 4. Lord Hives has a word with Mr. Peter Masfield, Managing Director, Bristol Aircraft Ltd. 5. Mr. James France, Chairman of the Institution's Education Committee, with Lord Hives.

In the final analysis, therefore, it might be that the fate of the world would be determined by the supply of qualified technologists and not by the hydrogen bomb.

Lord Hives had described how difficult it had been for him to spare one senior production executive to guide Packard engineers on the production of the Merlin engine during the last War. Sir Roy wished to refer for a moment to the available sources at the present time in this country, apart from industry, which were attempting to prepare young men for positions of executive authority in production engineering. Today there were several Chairs of Production Engineering in this country, but he believed that not a single one was filled, and there were many seats of learning which had taken the view that production engineering was not their business and that it was something which was below their academic standards. This, of course, was a tragic mistake, because production engineering must be accepted as a science and an experienced production engineer was a highly qualified man. In order to appreciate the great effort which was being made abroad to master production techniques it was only necessary to visit universities such as Cornell, Harvard and Princeton in America; Munich and Aachen in Germany; and Delft in Holland, to see the earnest attention that other countries were giving to production engineering and the breadth and quality of the four-year courses which large numbers of undergraduates were attending at each university on this subject alone. He believed that it was now probably too late for any appreciable effort to be made by British universities. We must look to the technical colleges to fill the gap and support those which had a progressive outlook. He thought this was the view which Lord Hives had expressed that evening.

Factory efficiency

Under the heading of factory efficiency, Lord Hives said: "if you are not satisfied with the efficiency of the factory, investigate the management", and he went on to say that his experience during the War had led him to admire the scheduling and forward planning in American factories. This interesting aspect of production engineering to which he referred had been little explored so far in this country, but when skilfully practised it called for a high quality man whose duties necessitated a considerable knowledge of mathematics.

In saying this, Sir Roy had in mind such subjects as operational research, linear programming, cybernetics, queueing theory and so on. These matters were not infrequently looked at more askance in this country than was production engineering, although they were part of it, and were regarded as more in the nature of Black Magic. He was afraid that this was due to the fact that at present we were in a state on such matters that was akin to that of some of the new techniques in the

medical profession, such as psychiatry, which could be a highly respected and qualified profession but in which there was a tendency for charlatans to flourish. There was little doubt, however, that if we in this country were to keep our place in modern engineering production, we must accept these new techniques and appreciate their value. He was glad to know that this subject was being taken seriously at Bristol University.

New aids to management

It was necessary to master these new aids to management. There was a new dimension of industrial management with which we must familiarise ourselves, the cybernetic dimension of liveliness. The details were all ready to hand, but they awaited the new techniques of mobilisation to weld them into a complete new structure. They were not in themselves, however, a panacea for the ills of vacillation, lack of production, or late delivery, and, as Lord Hives said, in the final analysis it all came back to the duty of administrative management to use these tools correctly, whether at ministerial level, in day-to-day Governmental control, or in industrial engineering housekeeping. Those who had heard Mr. Boyd Bucey, of the Boeing Company, lecture at the Aircraft Production Conference held by the Institution in Southampton in January last, would realise that even in the comparatively small quantity production of aircraft, these new techniques were used to some purpose. The remarkable speed at which a large new aeroplane was produced in America and the fact that it had been scheduled to fly 17 months ahead and had actually flown three weeks before the time scheduled, must have been due in no small degree to the contribution made by these techniques.

Lord Hives referred to the amount of money which industry spent yearly on technical education, and expressed the belief that the final responsibility for training the majority of technologists would rest with industry. This was certainly true for the big firms, but there was a far larger number of small ones in the U.K., and it was difficult for them to foot the bill. Apart from each firm's individual effort, over 100 of the country's largest industrial concerns had formed a fund guaranteeing over £3,000,000 for grants to schools for engineering education. The Government had planned to spend over the next five years about £80,000,000 on the expansion of technical education. This last figure might seem to suggest an awareness of the problem, until it was placed in perspective with our position not only with other countries, but also with our expenditure of 12 times as much a year on liquor and four times as much on advertising.

Lord Hives agreed that this country had slipped back so far as technical education was concerned, and attributed this to neglect over the last 10 to 15 years. Sir Roy regretted to say that this country had grossly neglected the subject for over half-a-century; and, although he agreed that they must now go

ahead quickly with the considerable sums which had been allotted to them, he doubted whether those sums were likely to be adequate to put Britain in a position to compete with confidence with other countries which had specialised in this subject for the last 25 years.

Lord Hives suggested that the educational system of this country should not be criticised for a longer period than the last 15 years, because the British Empire could never have been built up unless British universities had turned out large numbers of first-class Arts men, capable and qualified to go to the colonies and take over the responsibility of administration. Sir Roy felt that this statement required qualifying and showed only one side of the coin. He suggested that the journal *Technology* had provided the answer last spring, in a leader which concluded with the following words :-

"In Tudor times we were drawn across the oceans; in the 19th century our best young men were trained to administer the world. Today, the path is different but as plain. Scientific manufacture is our business, the source of our power, and the means of our livelihood."

Meeting the competition

Following on Lord Hives' comment on classical education, Sir Roy emphasised that if Britain was going to meet the enormous competition which was coming in the next decade, it would be necessary to get more boys of the top-notch class from the sixth forms of the public and grammar schools, which he believed was the best source from which to recruit the future Flag Officer type of qualified engineer. Educationists must be inspired to realise that engineering must have a fair share of the "talent pie" of British youth.

For generations past, the most promising up-and-coming British families had been led to believe that by taking a classical education they were equipping themselves most suitably for the senior and best-paid professions, and that, by and large, these did not include engineering. The tragic Suez fiasco, and the report by General Sir Charles Keightley on the Suez operation, should bring home to the schools and universities that the basic form of culture and education in this country for the future must have a strong scientific and engineering slant, and that our Prime Ministers, senior Service chiefs and civil servants, as well as leaders in industry, would need to have a technological training in the broad sense.

Lord Hives had also referred to the high standing of Russian professors in their own technical colleges and had asked: "Are we prepared to face up to this?" At present the short answer, Sir Roy regretted to say, was "No". If we were really serious about catching up, we should have to take action without delay to remedy the shortage of good teachers of engineering and science in the schools. Before the War, our sixth form teaching of physical

and mechanical science was probably the best in the world, but how should we fare in the future unless we could make the profession of teaching more attractive? Good engineering masters were a dying race in Britain today. It was necessary to get rid of the tradition which made the teaching of the classics "U", but the teaching of technology "non-U". Until it became respectable and more remunerative to teach technology than to teach a dead language, this serious deficiency was not likely to be made good.

Lord Hives made an important point at the end of his Paper when he said that Britain could not compete with the U.S.A. and Russia in numbers, but must do everything possible to compete in quality. He undoubtedly referred to the training of engineers, and with that Sir Roy entirely concurred. Both those countries had demonstrated, however, that in manufacture, contrary to what had so often been wrongly assumed in this country in the past, quantity and quality were not necessarily in opposition.

Lord Hives had concluded by saying :-

"I shall not consider that we are serious in our endeavours to produce more scientists and technicians until the universities and the technical colleges work much more closely together."

From practical experience Sir Roy would agree, and would like to add "and with more enthusiastic realism". Our problems were undoubtedly great, and possibly unique, but we ought to be seriously worried about how seriously we were behind Russia and America in the productivity race. It was the absence of a feeling of urgency and even, in isolated instances, of concern, about our position, together with the feeling that somehow we should muddle through, which was so exasperating.

He would like to thank Lord Hives again, and to close by quoting the recent words of wisdom of H.R.H. Prince Philip, Duke of Edinburgh, on this subject :-

"We have now in this country literally to live by our wits; by the wits of the scientist and engineer, who, by their inventions, start new industries; by the wits of the specialist and the expert, who can improve the methods of production and materials; by the wits of the designer, who can improve the product itself and its saleability; and, finally and most important of all, by the wits of the managers, who alone can bring together and make use of the ideas of the scientist, the specialist and the designer."

Principal G. H. Moore (*Bristol College of Technology*) expressed his pleasure at the opportunity to join in the discussion, although, as he was not an engineer, he would have to pass over the fascinating story in the first part of the Paper and reserve his comments for Lord Hives' views on technical education. It was no secret, he said, that they were hoping to make the closer acquaintance of the members of Lord Hives' Council in the next few months, and they trusted

that the outcome would be mutually satisfactory.

Looking through the first report of that Council, dated November, 1957, he had been most interested to see that there was, or had been at that time at any rate, only one course in production engineering which had been approved for the Diploma in Technology, although there were three which were combined Mechanical and Production courses. It seemed to him that this was entirely out of keeping with the national need, because surely on economic grounds alone this country required a strong body of well-qualified production engineers.

It might be that the reasons for this small number were lack of time so far and the difficulty of designing a course capable of standing up to the high and searching standards which Lord Hives' Council had rightly adopted. Another factor might be that the equipment essential for a production engineering course was extremely expensive. There might also be a lack of adequate numbers of well-qualified and experienced men to start the courses. It might even be that there was a paucity of students.

If the reason was the small number of students coming forward, he would commend to the Council that the number of courses should be small, because he was sure that it would be a mistake if in the early days of courses of this character so many courses were approved that the numbers attending were thin and inadequate to give a really strong and steady growth. If, on the other hand, the difficulty were that of designing courses of the required standard he had every sympathy with those responsible, because it was no light task.

Sandwich courses

Principal Moore was extremely interested in Lord Hives' view that for production engineering the sandwich course of training was ideally suited. He recalled that in the lecture theatre in which they were now meeting Professor Collar had, a year or two ago, expressed his personal opinion that the sandwich course of training was ideally suited to the profession of production engineering and that the Dip.Tech. would be a suitable award. Principal Moore heartily endorsed that opinion, though he was thinking of the ordinary sandwich and not of the "thick sandwich", which might, in some cases, produce indigestion.

It was true that to produce a Dip.Tech. course in production engineering required that the academic content should provide a discipline which would justify the label of "honours degree standard", and that that must be allied to good practical experience in suitable work, both in the college and in industry. He felt that a good regional college should have, in addition to the normal machine shops or machine tool laboratories, a well-equipped foundry, pattern-making and metal manipulating shops and gas- and electric-welding shops. Should that regional college aspire to achieve the status of a college of advanced technology, the Ministry would then say that all craft courses must go.

He did not want to give the impression that he thought that was a wrong decision. He thought that it was completely right, but it raised the question of where the production engineering student would get his workshop facilities. Was it an economic proposition for a college of advanced technology to install such workshops for the relatively limited use of such professional course students? If they were installed, would they be active enough in terms of well-qualified staff and sufficient jobs going through them to ensure that they were adequately tooled? He felt that the answer might be "No". If there should be near the college of advanced technology an adequately equipped regional college, the problem would probably be solved; he imagined that the Ministry would be willing to countenance C.A.T. students visiting a regional college, even though they might frown on regional college students going to a college of advanced technology. That was the way in which they would probably solve the problem, or would hope to do so.

He wanted to make those two points: (i) that the number of courses approved should be related to the potential need in terms of students, and (ii) that too rigid a segregation of staffs and students in professional courses from their opposite numbers in the final stages of craft courses was probably not to the benefit of either. He made those two points in terms of production engineering, but he was sure that it would be appreciated that they had a very much more general application.

Lord Hives, in reply, pointed out that the terms of reference of his Council were that they *approved* courses; they did not *design* courses, that being definitely left to the colleges. The task of the Council was simply to make sure that the facilities provided, the instruction and the quality of the staff were up to a certain standard. It should also be borne in mind that the Dip.Tech. was not intended to replace other qualifications, such as that backbone of engineering, the H.N.C., but was really an addition to them.

It would take some time for people to work out of their system the old, accepted methods of production engineering. In the past, the production side had tended to rely on bright apprentices coming forward. In future boys of that type would be skimmed off and go to a university. It might be said that this skimming off had to a large extent already taken place and, therefore, factories would have to adjust themselves to this fact and be prepared to take in university graduates, even if they had not done so in the past.

There was a story of a firm who were very concerned about the fact that they were losing business to a competitor, and they sent a man to investigate what their competitor was doing. This man came back with the report that they were producing a very good article, and he added "in spite of their having a bloody graduate in charge". Some people had not yet grown out of that attitude.

He would also criticise the production side for being a little mean with their staff. He mentioned

that because a wonderful business had grown up of consultants. He had used consultants, and they gave a very good "over the counter" service, especially when one had forgotten something or neglected something. The man in the factory was usually overloaded.

Many people had not yet properly digested the idea of production engineering at graduate level. He was sure that it would come and that it would have to come. That, however, was one of the reasons why there were Chairs of Production Engineering and no one to fill them. He had been asked whom he would recommend, and he did not know. Many people would have had the same question put to them.

Production engineering courses had been referred to. He had seen some of the courses, but the man who knew most about them was Sir Walter Puckey, who was Chairman of the Board of Engineering Studies, and went round visiting them. A point to be remembered in connection with the National Council for Technological Awards was that this was the first time that industry had poked its nose into the colleges and had lifted up the curtain to see what was behind it. Industry had now had an opportunity to see what was going on. On the other hand, it must be said that the colleges did not resent this; in fact, they welcomed it. In effect, they said: "We have been trying to get these things done for years, but nobody has ever listened to us."

It was for the production engineering side to put its house in order, because the trouble with consultants was that they always came in after the event. He had referred in his Paper to the maxim "Think before, not after". The consultants always came in after. He did not want it to be thought that he did not value their services, which were good. He had said to his people: "I think it is grand to get these chaps in, but don't get them to live here!". Production engineers must, therefore, get busy and put their own house in order. People had not adjusted themselves to the present-day position so far as production engineering was concerned.

Mr. S. L. Whitby (*H.M. Inspector (Engineering) for the South-West and Midland Regions*) said it had been very interesting to listen to Lord Hives' experiences, but he felt that Lord Hives had been a little unfair to the craftsmen and foremen who had helped to get the jobs done, because they were not mentioned in the Paper. Mr. Whitby suspected, however, that their part in getting the jobs done had been a valuable one.

He wished to give some figures for the South-West Region in relation to the City and Guilds machine shop engineering courses. In 1954 there had been 212 entries for the Intermediate examination; in 1957 there had been 613. The passes had also gone up three times. That was an indication of the efforts made in that Region to get men to go into the colleges, and he knew that his colleagues elsewhere had also been doing so. Having said that, he would like to make a plea that some of those who passed the City and Guilds Final should at a later age, in

the late 20's or 30's, have an opportunity to become corporate members of the Institution. The universities were sympathetic to mature students and special facilities had been provided for them. The Minister of Education gave scholarships to mature students at the present time. He hoped that the professional institutions would not make regulations which kept the late developer out, so that he felt frustrated.

Mr. Whitby said that because of the numbers taking the City and Guilds examinations he felt that 10% to 15% were first-class men who would make good managers. They might not be mathematically-minded and they might not be of the type to make first-class designers, but they could make good managers, and he thought that they had a place in industry and in production.

He made that point because he felt sure that in the story which Lord Hives had told the foremen and craftsmen must have done valuable work, and some of those men had achieved good positions. He hoped that that avenue would always be kept open. He believed that it was the University of Cambridge which gave the opportunity for a 'snob' (a boot and shoe repairer) to become a professor of classics. There was a danger in some of our thinking since the War. With the attention given to I.Q. and the labelling of a boy at 11 and putting him into a particular type of school, there might be difficulty in making an appropriate transfer later. He himself had started as a craft apprentice after leaving a grammar school at the age of 15, and he had obtained an honours degree at the age of 28. He hoped that Britain would never adopt the habit of certain countries on the Continent, of labelling people and putting them into a certain stratum.

Lord Hives wished to correct at once any idea that he did not give credit to the craftsmen and foremen. They were the people, he said, on whom industry depended. It must always be remembered that it was necessary to have training in depth. "Imagine waking up one morning", he remarked, "and finding one had six Nobel prizemen on the staff! What on earth would you do with them?". One did not want to have too many of such people. The whole structure depended on the craftsmen and the foremen, and his own firm, he thought in common with others, made sure that there was an avenue open so that craftsmen could go right through to the university at the firm's expense. They were delighted when that happened. There was no restriction anywhere. He was glad that the City and Guilds had been mentioned, because they were doing a wonderful job. The overall fact to be borne in mind, however, was that technical education had to have training in depth.

The **Chairman** said he had several more names on his list, and there would be others who wished to contribute to the discussion. He apologised to them for the fact that the lateness of the hour made it necessary to close the meeting, and asked them to send in their contributions in writing for inclusion in the report.

Mr. R. W. Hancock (*Chairman, Western Region of the Institution*), in proposing a vote of thanks, remarked that he had an uncomfortable feeling, after reading the Paper and listening to what had been said that evening, that they might be putting their noses too closely to the grindstone of technological education. He found it a disquieting thought that the two countries most associated with technological progress had produced the worst brand of Communism and McCarthyism.

They all felt privileged that evening in having been able to listen to Lord Hives, who was one of the leading engineers of our time. Lord Hives had dipped into his experience and had given them all

the benefit of wisdom acquired from nearly half-a-century of leading a Company, the name of which was literally a household word. The members of The Institution of Production Engineers had had a double pleasure that evening in entertaining such a distinguished body of guests that he felt quite unable to do justice to them. In proposing the vote of thanks, therefore, he would like quite simply to thank all of them for making this delightful evening possible, and invite the whole audience to join with him in offering their sincere thanks to Lord Hives.

The vote of thanks was carried by acclamation and the meeting then ended.

CORRESPONDENCE

From: **Mr. James France** (*Head of the Department of Industrial Engineering, Loughborough College of Technology and Chairman of the Institution's Education Committee*).

The impression given by Lord Hives' Paper is that he sat down and wrote just what he wanted and it makes delightful reading and hearing as a consequence. His reminiscences of overseas manufacture of Rolls-Royce engines confirm the supremacy of British product design and development. None of us, however, is so sure that we have supremacy in production.

To those of us who have been concerned through the years with the development of production engineering education, the establishment of the Diploma in Technology is invaluable. When a course has won through the searching criticism of the National Council for Technological Awards, no longer can it be considered as deficient in intellectual discipline, as some people would have us believe.

Principal Moore's remarks are interesting. With regard to his ruminations on a number of points, he might be interested in the views of the Head of the Department which is operating that one approved course in production engineering which he mentions.

The small number of such courses may be due to lack of time as he suggests. On the other hand, it may be due to lack of courage. Everyone agrees that "this country requires a strong body of well-qualified production engineers" — the technical colleges have got to have the courage to make such courses available. The fact that one course in production engineering has been approved already by Lord Hives' Council is proof enough of the possibility of designing such courses capable of standing up to the high and searching standards — there is no reason why many others should not follow. Study of the Institution's new examination syllabuses will provide some help in this regard. The recruitment of

qualified and experienced staff is not easy, but this is a common experience in all professions today. Production engineering is a compound of many different disciplines and one must not expect to be able to find them all centred in one individual — not for a few years to come anyway. Consequently, it is necessary to build a team, each member of which specialises upon some particular aspect; thereby the necessary high overall standard can be achieved.

Misplaced regret

The regret expressed at the divorce of craft courses from the colleges of advanced technology is surely misplaced. As far as production engineering education is concerned it is undoubtedly a great blessing; no profession in recent years has suffered so much from this misguided link. There is no greater "built-in drag" (to use Lord Hives' phrase) upon the academic standard of a production engineering course than to have it mixed up with craft training. Maybe this is one of the reasons why so few colleges have been able to lift their sights to the level of Dip.Tech. standard.

Mention was made—"that the equipment essential for a production engineering course was extremely expensive", and also that a college should have machine shops, a well-equipped foundry, pattern-making and metal manipulating shops, and so on. There is quite a lot of wrong thinking here, one erroneous idea giving rise to another. The opinion has been expressed that the sandwich type course is ideally suited for production engineering. Why is this so? It is because the student receives half his training in industry — the place where "machine shops, well-equipped foundries, pattern-making and metal manipulating shops" and so on already exist. It is the job of industry to look after this aspect

of a student's training and it is not for the technical colleges to duplicate either their efforts or their expensive plant. Industry can teach "How" a job is done very effectively; the colleges' task is to teach "Why" — to deal with the underlying principles of production activities. They will need well-equipped laboratories for this, it is true, but such are not merely pale shadows of industry; they may well have equipment in them which is never seen in an industrial shop. The expense is comparable with that for well-equipped mechanical or electrical engineering laboratories.

Finally, there is the question of numbers of students available and the support given by industry. The bold policy pursued at Loughborough has been well rewarded by the very generous support from industry resulting in an almost embarrassing number of students. The late Mr. C. B. Cochran, when asked what was the secret of a successful theatre show, said: "The public knows exactly what it wants — when it gets it!". Judging by the value of the student-apprenticeships which so many industrial companies are putting up for production engineering courses — they are far more valuable than any State scholarship — it appears that industry knows what it wants too!

From : **Mr. J. A. Bailey**, M.I.Prod.E. (*Bristol College of Technology*).

Lord Hives has undoubtedly sounded the right note by using his reminiscences to make us consider what sort of qualities we should aim to develop in our student production engineers. Not all of them will be called upon to make major decisions in the international field; but without exception they must acquire the knowledge and confidence to make up their own minds, and to lead their followers, in the business of getting things produced to meet demand, and of keeping men and machines and processes usefully employed.

As an Institution with the needs of the country at heart, we wish to utilise every possible means of seeking out the right young men and giving them this knowledge and confidence. As an individual, it has fallen to my lot to assist in designing one sample of the particular type of course advocated by our distinguished Viscount Nuffield Lecturer, as being so eminently suitable for our profession. The ideas, which are shared with my colleagues and have been culled from many sources, have not quite crystallised into an accepted scheme; but a brief account of the principles behind one set of detailed proposals for a Diploma in Technology course in Production Engineering may be of interest in the discussion of this Paper.

In the first place, due regard must be paid to the needs of industries which are likely to support students in the proposed course from its inception, as well as industries which show signs of settling or growing in the neighbourhood. The South does not seem likely to compete with the heavy industry of

the North; but even our pleasantly rural South-West has an astonishing variety of manufacture, ranging from ships to aeroplanes, from ceramics to nuclear products, and from brewing equipment to railway signals.

In general, we are interested in a combination of precise and sometimes complicated machining, with an increasing use of the casting, joining and pressure-forming processes. These processes are applied mainly to metals, including some of the newly developed metals and alloys; but also to a significant variety of non-metals used both for tooling and for the final product.

We also have in mind the shortage of knowledge, to which attention has been directed. It is still difficult to find time for really sustained research, but in the production engineering field we expect to work on the frontiers of learning, first in production metallurgy, with metrology coming next, and after that the problem of communicating instructions from the human brain to automated machinery. In the course of helping our colleagues in other departments to build up special equipment, we have become acquainted with their modes of research, and have also realised how much mutual help can be obtained in a many-sided College.

Four-part curriculum

The curriculum itself we have divided into four parts :

- (i) fundamental science and mathematics;
- (ii) machining, tooling and metrology;
- (iii) casting, forming and welding; and
- (iv) management and control.

Fundamental subjects are compulsory throughout.

From each of groups (ii) and (iii) one item is taken to a high level in the final year. The practical project undertaken by the student will be related to one of these selected subjects, or to the subject selected from group (iv). In the earlier years all items from groups (ii) and (iii) are taken, with a view to producing men who are very broad-based in production technology.

In management training we do not want to go too far too early. Based on considerable experience, we feel that "Management of Men" is best taken as a post-Diploma study. On the other hand, introductory courses in Industrial History and Administration have proved their value as a liberal study at a level equivalent to the last two years of the Dip.Tech. course. Work Study, Applied Statistics and Operational Research, and Control Engineering following Electrical Instrumentation, are alternatives from which one may be chosen for the last two years.

We hope that training on these lines will enable a high level of final studies to be built upon a sound and broadly based course, and so encourage the emergence of the type of men Lord Hives has pictured for us.

Sixth Conference on "PROBLEMS OF AIRCRAFT PRODUCTION"

Southampton, 2nd/3rd January, 1958

Theme : "U.S. — U.K. PRACTICE"

The Sixth Conference on "Problems of Aircraft Production", promoted by the Southampton Section of the Institution, took place on 2nd - 3rd January, 1958, at the University of Southampton (by kind permission of the Vice-Chancellor). This issue of the Journal contains a report of Sessions III and IV. The first part of the proceedings appeared in the March Journal.

OPENING LUNCHEON

Speakers : G. T. DICKS, J.P., Mayor of Southampton.
JAMES F. GRADY, United States Consul in Southampton.
Chairman : D. L. WIGGINS, M.I.Prod.E., Chairman, Southampton Section.

SESSION I

(The Lord Sempill Paper)

"MANUFACTURING IN THE AERONAUTIC AGE"

Speaker : BOYD K. BUCEY.
Chairman : The Rt. Hon. THE EARL OF HALSBURY, F.R.I.C., F.Inst.P.,
M.I.Prod.E., President of the Institution.

SESSION II

"MANUFACTURING PRACTICE — A REVIEW OF THE BRITISH AIRCRAFT INDUSTRY"

Speaker : L. G. BURNARD, A.F.R.Ae.S., M.I.Prod.E.
Chairman : E. F. GILBERTHORPE, A.M.I.Mech.E., M.I.Prod.E., A.M.B.I.M.

SESSION III

"SOME ASPECTS OF THE DESIGN, DEVELOPMENT AND MANUFACTURE OF THE P1 WING"

Speakers : F. BRADFORD, A.F.R.Ae.S., and G. H. TAYLOR.
Chairman : J. B. TURNER, M.I.Prod.E.

SESSION IV

COMBINED DISCUSSION ON ALL PAPERS PRESENTED TO THE CONFERENCE

On the platform : BOYD K. BUCEY ; L. G. BURNARD ; F. BRADFORD ;
G. H. TAYLOR.
Chairman : S. P. WOODLEY, M.B.E.

SOME ASPECTS OF THE DESIGN, DEVELOPMENT and MANUFACTURE OF THE P.1 WING

by F. Bradford, A.F.R.Ae.S.

and

G. H. Taylor

PART I

Introduction

IN order that this Paper may be presented, certain security restrictions have been relaxed but only insofar as discussion is permitted on the subject matter disclosed in the Paper. I am sure you will understand that due to the nature of the ultimate product, there are limitations on what we can describe, and for that reason, I must ask you to bear with us where we have been unable to give as full or comprehensive a description as we would have liked.

This joint Paper attempts to explain and illustrate how the often conflicting requirements of design and manufacturing departments have been co-ordinated to facilitate production.

We believe that the close and constant liaison which was maintained between the departments has enabled us to achieve the most effective combination of both design and production features. The result is a supersonic wing of high performance and efficiency which can be manufactured by simple and well tried production methods.

The P.1 aircraft

The P.1 is a fully supersonic single-seat fighter with a very advanced weapon system, and equipment enabling it to operate in all weathers by day or by night (Fig. 1). The wings have a sweep back of 60°, are of a moderately thin section and are fitted with the usual flying control surfaces (Fig. 2).

The airframe has the usual breakdown into the main components of fuselage, wings, tailplanes and

fin. The order of assembly is, however, unusual in the case of the wings to fuselage, each wing being built independently and joined together at the aircraft centreline, forming a continuous span-wise unit (Fig. 3).

The wing structure

Each wing has a main structural unit or torsion box, part of which is sealed off to contain fuel in a pressure-tight compartment. To this unit are attached the leading and trailing edges, tip structure and ailerons (Fig. 4).

Due to the shallowness of the wing-box, the production shop personnel could not be expected to assemble the unit in the usual manner, where the structure is built up in skeleton form and the outer skins subsequently attached.

Further, since squeeze-riveting was considered essential for fuel tightness, the limited access did not permit the entry of a riveting machine capable of applying sufficient force to close the rivets.

The restricted access, the need to maintain a very high standard of sealed riveting, the effective sealing of permanently attached structure and the exclusion of all drilling on the final assembly stage decided, apart from the aerodynamic and stressing cases, the following requirements on which the design was to be based:

1. The assembly of all structural members to the skin panels in an open condition to permit sealing of the structure and obtain the best possible access for riveting.
2. Separate components of the structure to be kept to a minimum.

Fig. 1. The P.1 aircraft

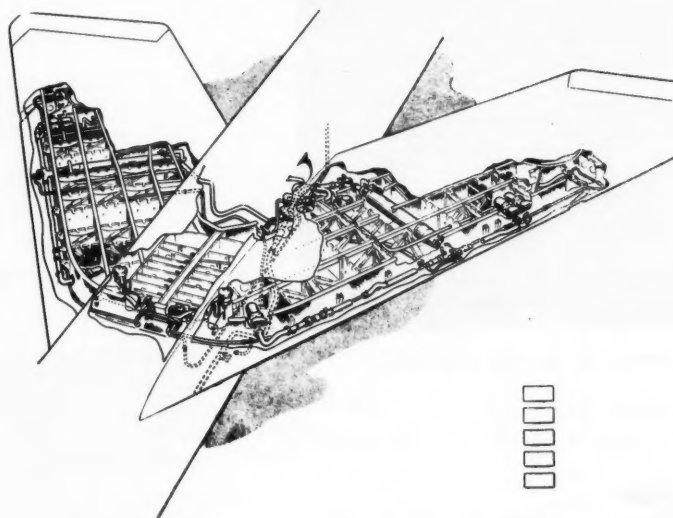
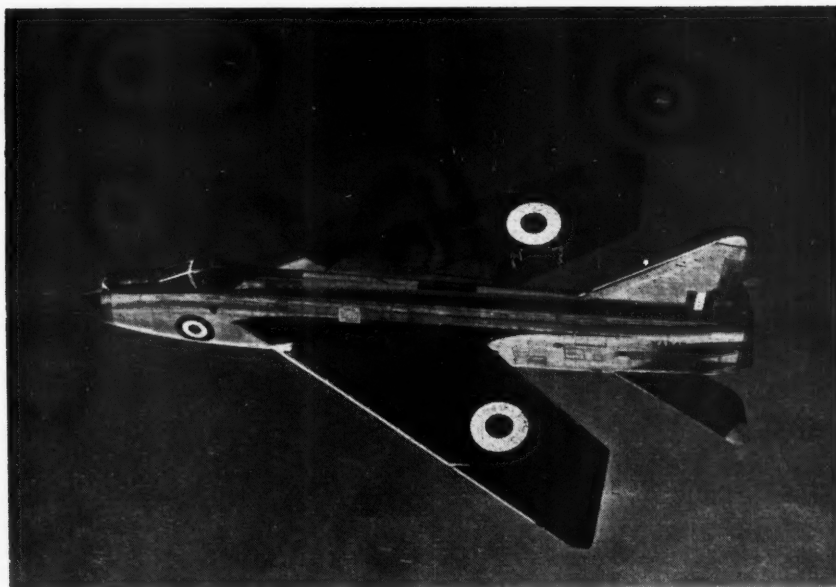
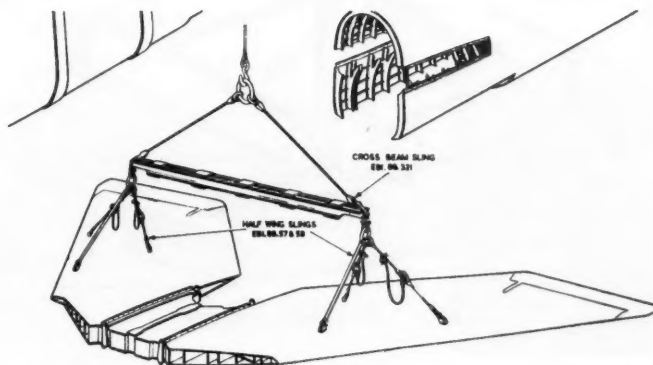


Fig. 2. Sketch of wing assembled to fuselage

Fig. 3. The wings completed as a single component



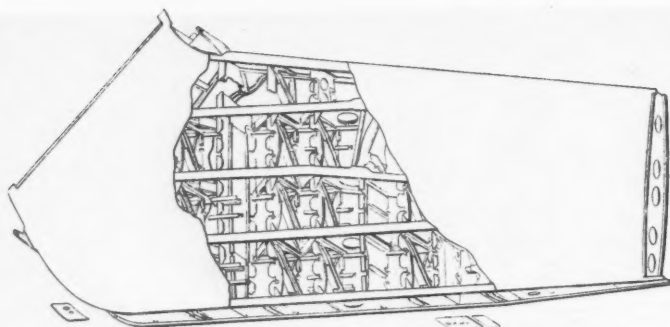


Fig. 4. The wing box

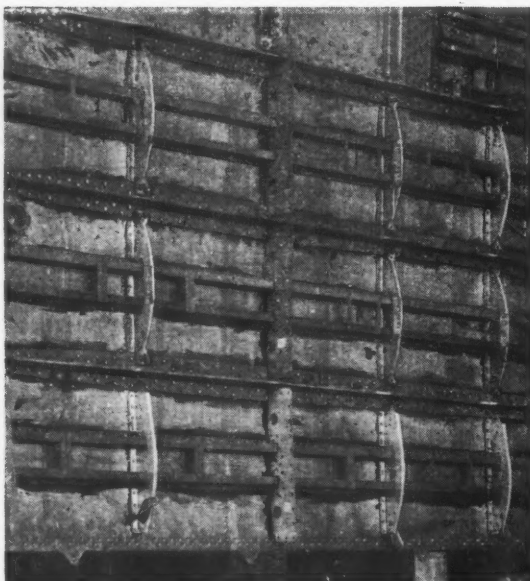


Fig. 5. A portion of the skin component

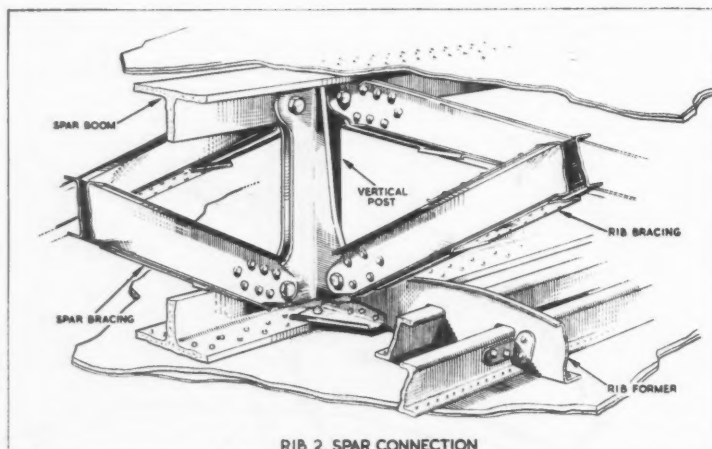


Fig. 6. Sketch of structure connection between ribs and main spars

3. Minimum of final assembly work inside the confined space of the tank.
4. Consequent upon 3, and to prevent contamination of sealant by swarf, the elimination of all drilling at the final stage of assembly.
5. Avoidance (where possible) of skin and structure joints in the tank area.
6. Simplification of connections inside the structure by elimination where practical of multiple bolted or riveted joints.

Skin component

The skin panel is cut from a large sheet of DTD.687 .2 in. thick (Fig. 5).

The inboard end of the skin panel is reinforced by the addition of thick laminations, and the outer end reduced in thickness by controlled depth routing. By careful arrangement of the reinforcing and locality of machining, it has been possible to maintain a uniform stress distribution.

The choice of this skin thickness with additional reinforcements depended at the time on the availability of material, the size representing the maximum which could then be obtained.

Internal structure

The internal structure consists of five spars. Between each pair of spar booms are two extruded stringers, each being riveted to the skin panel. Crossing these are rib members similarly attached.

The main essentials for these internal spars and ribs are booms, diagonal bracings, and vertical members or posts between the booms (Fig. 6). The

vertical posts provide a combined attachment for both rib and spar diagonals, and only the latter is required to be inserted on the final assembly.

This type of construction was chosen primarily because of the extremely limited access during the build-up and also due to the arrangement of jig control and method of assembly; the diagonal bracings with one bolt at each end were far simpler to locate and attach than shear webs with a multiplicity of fixings (Figs. 7 and 8).

Tank unit assembly

Each spar is provisionally built up on its individual jig, and then transferred to the assembly jig, where all locating pads, holes, etc., are repeated. These are to ensure accurate alignment later when the units are brought together for final assembly, and permit also the fitting and drilling to occur on the dry structure, i.e. without the presence of sealants.

The remainder of the skeleton structure is assembled and each skin offered up in turn for location drilling. The structure is then dismantled and after the drilling for rivets and bolts has been completed, the elements of the structure which are fitted to the skin are thoroughly cleaned, the inter-faying surfaces coated with sealant, and passed through the riveting machine.

This machine is described later in the Paper.

Final assembly of tank unit

When the bottom skin component has been sealed and riveted, it is returned to the assembly jig and all spar verticals and rib diagonal bracings are fitted. Only the bottom fixings of each of these parts can be



Mr. Bradford joined The English Electric Company Limited in 1945, became Assistant Designer in 1950, and Principal Designer in 1952. He was responsible for the Canberra wing design, and is now in charge of P.1 structural design, at Warton.

From 1934 to 1945, he was on the design staff of The Fairey Aviation Company, and was previously with Short Brothers, at Rochester.

Mr. Taylor commenced an indentured apprenticeship in 1916 with Alfred Herbert Limited, at Coventry. He joined Armstrong Siddeley Motors Limited in 1923, subsequently becoming a machine shop foreman and Planning Engineer.

He joined The English Electric Company Limited at Preston in 1939, as Chief Process Planning Engineer, and is now Aircraft Development Engineer for the Aircraft Division at the Preston works.





Fig. 7. Structure being assembled to bottom skin component

Fig. 8. Structure being assembled to bottom skin component

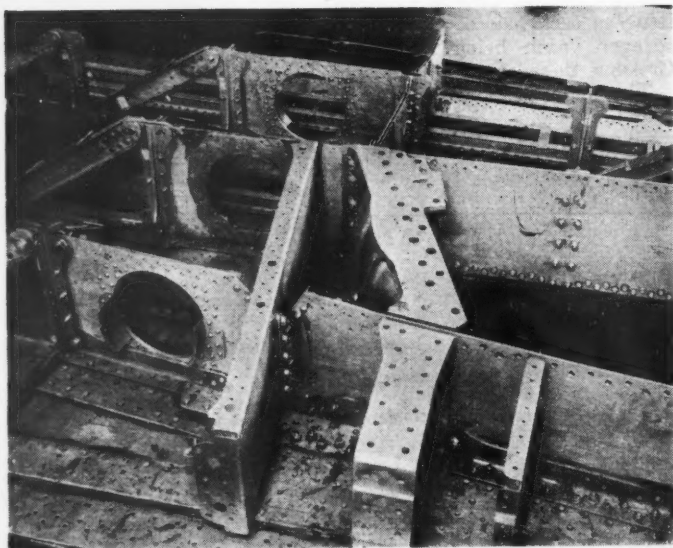
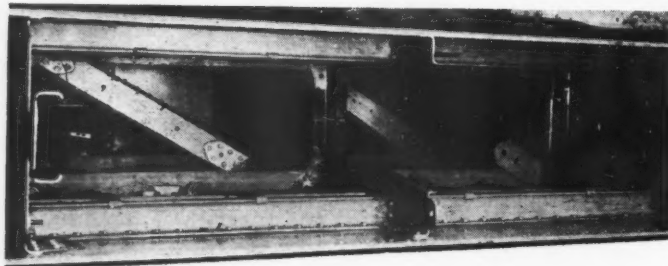


Fig. 9 (below). Side of wing box illustrating



completed at this stage. The top skin is then lowered into position and the remainder of the internal structure completed, working progressively outwards from the centre.

It is during this stage that the amount of work necessary inside the structure has to be kept to a minimum, since the gap for access is seldom more than 8 in. deep (Fig. 9).

Development and testing

Apart from the usual test work associated with any structural development, there were some aspects requiring investigations relating to maintaining a pressure-tight fuel tank, since it was considered essential to attain 100% sealing even under extreme conditions. Earlier experiments had proved the failure of sealants, subsequently applied to completed structures, to seal effectively, and that where possible more than one line of defence against leaks should be provided. Therefore, development work was necessary on the following main problems relating to the fuel tank:

- sealing of corner joints;
- sealing of access panels;
- improvement of riveting and bolting techniques;
- sealing of gaps in the structure.

Previous experience had shown that statically pressure testing a tank was of little value and the only way to prove the efficiency of the sealing, was to apply a racking load to the tanks, whilst under pressure. Accordingly, model tanks were built, representative in all detail of the actual aircraft tanks. The various interfacing sealants, structure joints, access panels and types of riveting were tested repeatedly under the severest conditions.

Fig. 10 shows one of these model tanks in the test frame. The tank is sandwiched between heavy steel plates, supported at two diagonally opposite corners and loaded unsymmetrically at the other two.

The test schedule, based on AP.970 requirements, included:

- repeat loading to 40% design load with the tank pressurised to 7.4 p.s.i.;
- at each 100 cycles, pressure increased to 13.5 p.s.i. and held for 20 minutes; pressure was then raised to 23 p.s.i. and held for one minute;
- in addition, tests were carried out at extreme temperatures from -47°C to $+95^{\circ}\text{C}$ and at similar loading and pressure cycles.

Regular inspections of the tanks under test enabled a case history to be compiled from which further investigations or improvements were decided upon. Fig. 11 shows a typical report.

This indicates the failure of the standard rivets used in building the tank to remain leak-proof, even though well sealed by coating with sealant before closure and later brushed over with a heavier type of sealing medium. Also the tests indicated the efficiency of the rubber block type sealing of the corners, though naturally there were many difficulties to be overcome before a really satisfactory solution was reached.

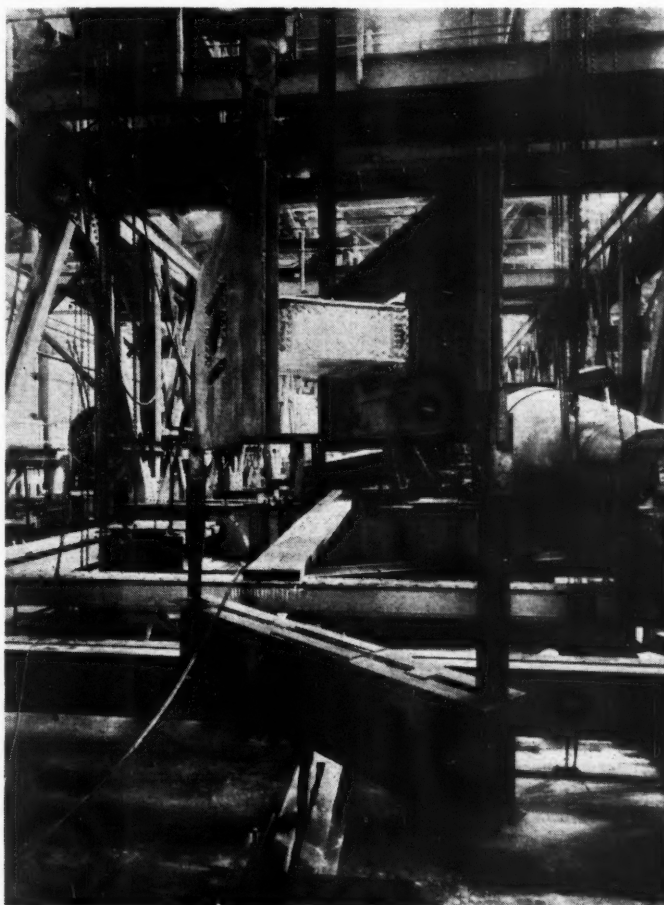


Fig. 10. Model test tank

Cycles completed	Internal pressure lb./sq. in.	Observations
100	7.4	Slight seepage at 4 rivets top skin, 1 rivet bottom skin and 2 bolts in spar web.
	13.5	Seepage as above plus very slight seepage at one bolt in access panel.
200	7.4	Seepage as for 13.5 p.s.i. continuing.
	13.5	No change. Affected bolts replaced. Rivets replaced by special bolts.
	13.5	1 rivet in each skin seeping.
	23.0	No change.
300 to 900	7.4	6 rivets in top skin, 1 in bottom skin seeping.
	13.5	No change.
1,000	7.4	Rivets as above, no increase, slight seeping at corner block at 965 cycles.
	13.5	Held for 20 minutes — no change.
	23.0	Held for 20 minutes — no change.

Fig. 11.

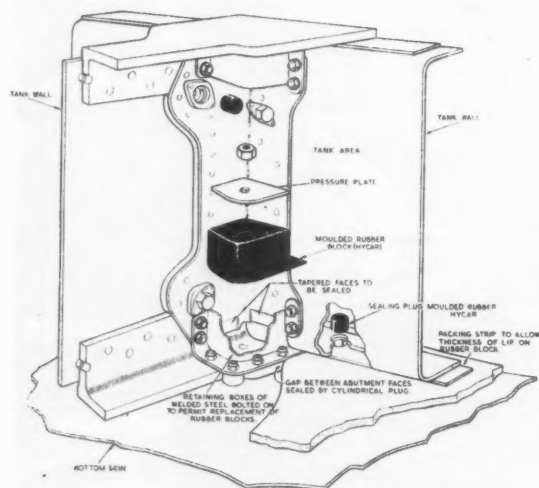
Corner sealing

One of the most serious effects of stress applied to a tank is distortion at the corners. The three faces forming the corners are invariably slightly changing their angular relation to one another and this, coupled with the variety of sections meeting to form the corner, probably make these the most critical of all joints to seal.

Any rigidly attached seal, which cannot withstand slight displacement, is most likely to leak under load. Figs. 12 and 13 show a typical corner design where by use of a resilient form of seal, intimate contact

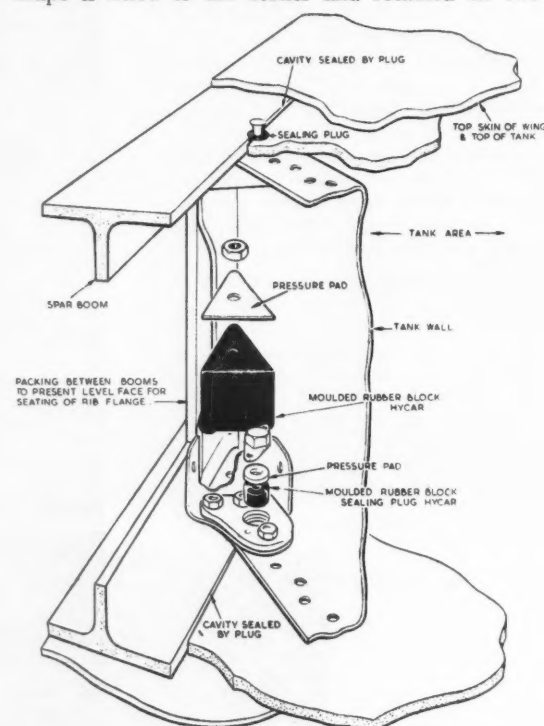
between the sealing block and tank walls or skin is maintained continuously.

A synthetic rubber block moulded to a comparative shape is fitted to the corner and retained on two



INTERNAL SEALING OF TANK CORNER JOINT

Fig. 12. Sketch of corner joint.



EXTERNAL SEALING OF TANK CORNER JOINT.

Fig. 13. Sketch of corner joint

outer faces by a wall extending slightly above the level of the block. A bolt passes through the rubber block and metal pad into a retained nut capable of free vertical movement. Tension on the bolt applies pressure to the metal pad and consequently on to the rubber, which is thus forced into the desired intimate contact with the surfaces of the corner. The actual hole in the extreme corner is not itself sealed; instead, the leakpaths to it are isolated by blanking off the approaches.

Joint sealing

As in all structures, certain members must butt up against others, and it is a production advantage if the gaps between them can be generous. These can, however, be a hazard for effective pressure tightness, and many devices were tried before the following satisfactory solution was evolved.

The corner joint described above includes certain of the seals developed to prevent leaks through these

gaps. The design again relies on a rubber block being forced into intimate contact with the surfaces surrounding and across the leakpath.

Through both adjacent members where the gap exists, and through a top packing plate, a hole is drilled to suit the rubber plug, stopping at the inside skin level. Again, the same technique of applying pressure to the rubber by means of a bolt and pad is used as in the corner joint. An additional item is required, that is the top packing plate to provide a complete circumferential seal above the level of the gap.

No attempt is made to fill the cavity between the abutting parts, but simply to seal all the faces which are in contact with the rubber.

As an indication of this type of sealing, to fulfil the requirements of pressure tightness and give to the production shops the advantage of considerable variation in gap size, a total of 60 seals of this type are fitted in each wing. After over four years of

FIREPROOF TANKS LTD. Experimental Department Report				REPORT L144 No. DATE 19.9.51	
SUBJECT	DEVELOPMENT OF RUBBER CORNER BLOCKS FOR P.1 AIRCRAFT				
Standard Moulding Grade No.	Shore Hardness	Test Fuel Spec.	% Change in volume after immersion for 48 hrs. at 40°C	% Change in volume after drying for 18 hrs. at 100°C	
HE/4	65.70	DERD. 2482 Aviation Kerosene	+0.61	—3.0	
		RDE/F/541	+0.90	—3.5	
HP/257	67.74	DERD.2482	+12.65	—1.5	
		RDE/F/541	+13.19	—4.95	
314	54.59	DERD.2482	+12.0	—13.25	
		RDE/F/541	+7.5	—13.25	
328	43.48	DERD.2482	+0.5	—2.96	
		RDE/F/541	=0.6	—2.94	

PRESSURE TESTS — RESULTS

1. *HE/4 Blocks*

(a) At room temperature (22°C). No leak after 30 minutes at 30 p.s.i.

(b) At 70°C. No leak after 10 minutes at 30 p.s.i.

(c) At -50°C. Slight leak at -35°C. Tank allowed to warm up, clamping bolt tightened.
No leak at -50°C after 10 minutes at 30 p.s.i.

2. *HP.257 Blocks*

(a) At 22°C. No leak after 30 minutes at 30 p.s.i.

(b) At 70°C. No leak after 10 minutes at 30 p.s.i.

(c) At -50°C. Leaks occurred at 30 p.s.i. and could not be stopped.

RECOMMENDATIONS

Hycatrol HE/4 most suitable for this application.

Loss in volume relatively small, and blocks made from this material effectively seal test tanks against a pressure of 30 p.s.i. over a temperature range of -50°C to +70°C.

Fig. 14. Test Report on rubber blocks

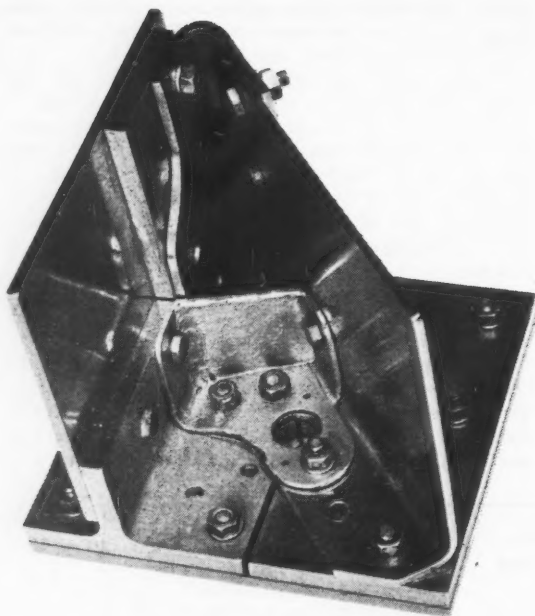


Fig. 15. Sample corner joint used for moulding rubber blocks

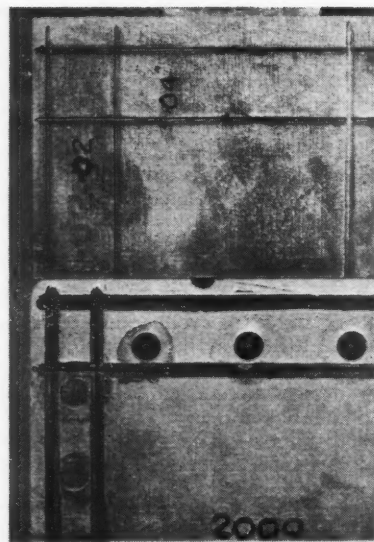
continuous use, these are still functioning satisfactorily and no replacement has yet been necessary.

Rubber block moulding

Coupled with the design of the corner sealing were the developments of a satisfactory rubber material, to withstand total immersion in kerosene and drying out over a wide range of temperatures, and also the manner in which the various shapes of sealing blocks were to be manufactured. The ultimate choice for production would naturally be a series of moulding dies, each representative in shape to the corners requiring seals, but for the prototype aircraft a more rapid method of manufacture was desirable.

The material ultimately chosen to withstand a temperature range of -50°C to $+100^{\circ}\text{C}$ was Hycatrol H.E.4. This showed a minimum loss due to immersion in kerosene and remained flexible at the lowest temperature (see Fig. 14).

Since the arrangement of the design for sealing depended on a pressure application, and this is also a condition of rubber moulding, experiments were carried out with the intention of simplifying, for small quantity production, the moulding die manufacture. This resulted in building up, from representative structural sections, replicas of the corner joints identical to those on the aircraft. In this way all the peculiar shapes, radii, tapers, etc., were produced naturally by the structural sections much more rapidly and more cheaply than by the usual die-sinking techniques. Fig. 15 shows a typical mould made for sealing blocks used in the corner joint illustrated previously. As can be seen, the



The photograph above illustrates, in a representative way only, the arrangement of groove in the steel mould for manufacture of the rubber sealing section, with a corner of the actual door and seal enlarged. The steel mould in this case is only a sample and two sizes of groove are illustrated.

The drawing underneath shows the section of the steel mould as produced by passing a single roller over the surface of the steel plate producing a groove with burrs thrown up on either side. These burrs produce a recess in the rubber section when moulded, to provide space for the deforming of the rubber when the door is bolted on to the structure.

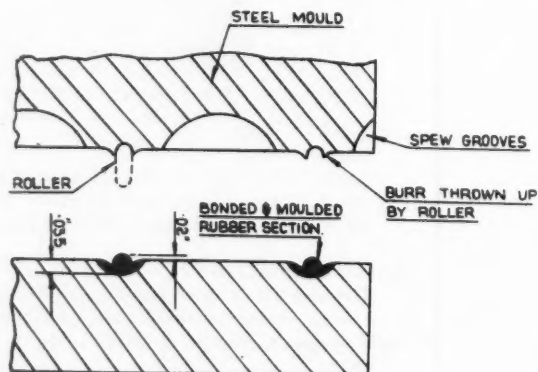


Fig. 16. Access door moulding

parts used in its construction are as on the actual wing, all the existing details, lofting, etc., being used.

Sealing of access panels

Two types of panels form the closure of the tank unit and since they form the webs of the spars, are required to carry shear loads. To ensure maximum shear efficiency from the joints of the webs to boom flanges, no gasket type sealing is employed. Instead, for panels requiring infrequent removal, the sealing is by a nylon monofilament .005 in. thick laid in two parallel lines close to, and on either side of, the bolting lines and retained in position by a thin adhesive coating.

The panels providing access for servicing of equipment buried inside, and for inspection of the tank, have an integral seal permanently fitted, which does not require refitting on subsequent replacement of the access panel.

This type of sealing was really derived from the actual development of the dies for its manufacture.

The requirements were for a bead of rubber projecting slightly above the surface to present an interference with the surface to which it should contact, and adjacent cavities either side of the bead, providing space for the deformation of the rubber.

Fig. 16 shows an example of the moulding die shape and a corner of a panel after moulding.

The die is made by passing a roller over the surface of a steel plate, the effect of indenting by the roller throwing up a burr on either side. These burrs mould into the rubber the cavities described previously. The access panel is grooved coincident with those in the die, equal to the width over the burrs.

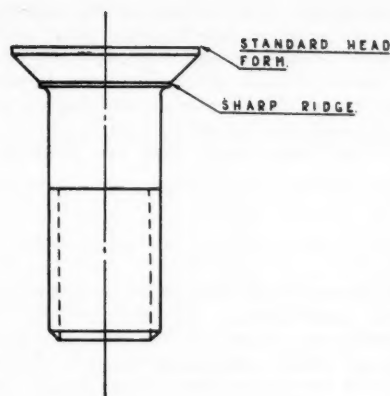
The rubber section is moulded directly on to the access panel by using the latter as one half of the die, and applying to this a bonding agent. The seal is in this way permanently formed and attached to the panel.

Riveting and bolting

Due to the limited access to the interior both during and after building the tank, it was essential that a really satisfactory sealing of the bolts and rivets, particularly through the skin, was obtained. If leaks were found during the routine pressure testing on the production wings, the breakdown of the structure to permit repairs would be a serious interruption and further, as stated previously, it was essential to maintain a leakproof tank in service for reasons of safety.

Fig. 17 shows the bolt design ultimately chosen after considerable development and testing.

A small ridge is produced on a standard countersunk head form which bites into the material in which the head seats, and becomes self-sealing. As an additional safeguard, however, sealant is applied to the bolt shank before insertion; though all tests



SPECIAL RIDGED HEAD BOLT.

Fig. 17

on these bolts were carried out without any sealing medium other than the ridge.

The type of rig developed for the testing of the bolts is shown in Fig. 18. By the addition of a pressure-box behind a shear-test specimen, the sealing characteristics of the bolts whilst subjected to load and pressure were established.

The results obtained from the tests on these bolts are shown in Fig. 19.

The rivet sealing is very similar but in reverse. Since the rivet material is softer than the skin, the ridge would flatten during riveting, so instead this is formed in the countersinking of the hole (see Fig. 20).

The first type of cutter made to produce this type of hole was purely a standard countersinking bit, with small right-angle nicks in each cutting face. Though this made a ridge, the corner was radiused, as experience had shown that a really sharp edge was essential for sealing. The final type of tool developed comprised two cutters, the first flat-sided to produce the bore between the ridge faces; the second a hollow truncated countersinker located over the shank of the first, and forming the top surface of the ridge and the remainder of the countersinking.

The rivets were tested in the same manner as the bolts and all pressure testing carried out with the rivets unsealed. Fatigue testing of both rivets and bolts showed no adverse effect. It was thought the notching effect of the bolts in the skin material, and similarly in the rivet head would have proved serious, but this was not the case.

A typical test report is shown in Fig. 21, and Fig. 21(a) illustrates a test specimen after failure.

Tank sealing

To ensure that the fuel compartment retains its pressure tightness under all circumstances and conditions in service, the sealing wherever possible is at

least duplicated. The surfaces of any adjoining parts are coated with an interfaying sealant and a fillet of slightly heavier sealant applied along each edge.

All rivets, though self-sealing, are dipped before closing in the same material used for the structure sealing, and a fillet of sealant applied to the panned head. The ridged-head bolts are similarly coated

with sealant before insertion and, in addition, special ring washers which seal both the shank and the inside face of the structure are fitted under the nuts.

The bolts through the outer spar web and access panels, have sealing washers both under the heads and under the nuts.

PART II

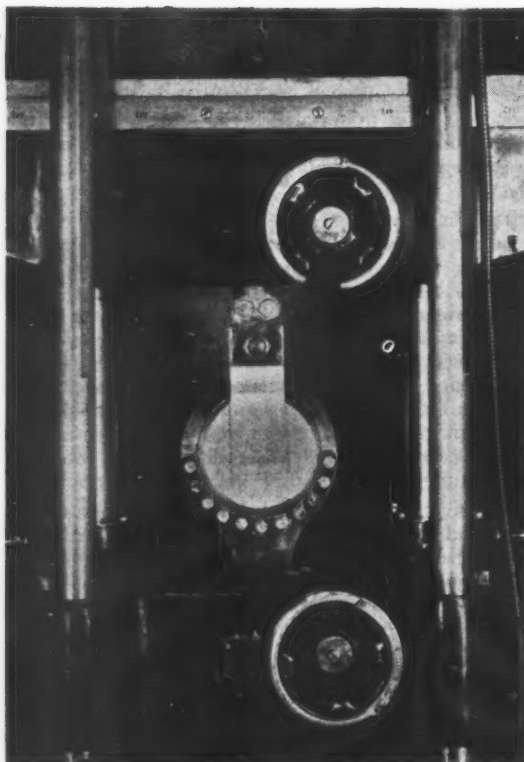
We have already said that the design and production organisation behind the P.1 building programme is a matter of close co-operation between the design office and the factory. Mr. Bradford has given you an explanation of the design considerations in the P.1; now it is my task, as one of the production people, to talk about the manufacturing considerations. The main problems arising from the design proposals were concerned with utilising the facilities already available for the rapid production of the prototype.

Farnham Rolls were available for rolling the skins to

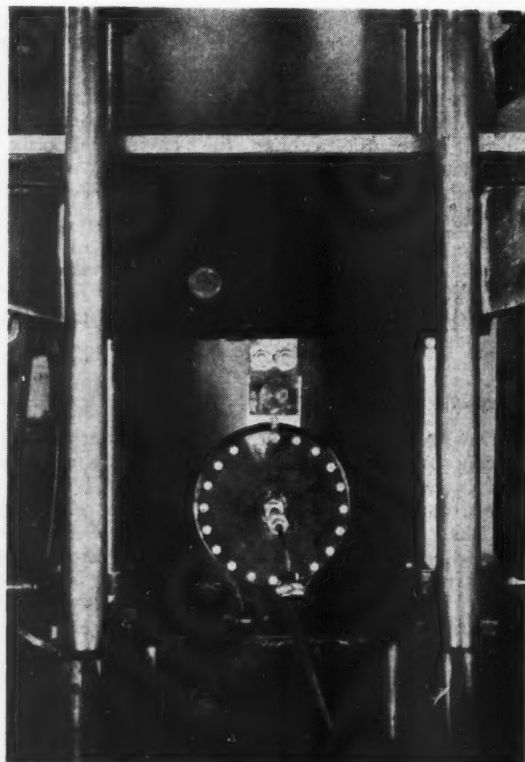
curvature. A skin routing machine had to be constructed to rout the profile and rebate the skins. A decision was made that despite the strength of the skins and their allied structure, jiggging would have to be substantial and in conformity with recognised production standards to achieve the degrees of accuracy required.

Skin manufacture

The length of skin ultimately exceeded the length of the available rolls, which illustrates how existing facilities frequently fall short for the next require-



Front view, showing specimen assembled in rig



Rear view, showing pressure connection

Fig. 18. Test rig for special bolts and rivets

Fig. 19. Report on special bolt tests

TEST REPORT ON RIDGED SEALING BOLTS								TEST NOTE N° 392
SPECIMEN & N° OF BOLTS.	EB102-323 6 OFF 5/16" DIA	6 OFF 5/16" DIA	6 OFF EEAS 101/3E	6 OFF EEAS 101/3E	6 OFF EEAS 101/3C	6 OFF EEAS 101/3C	6 OFF EEAS 101/3C	6 OFF EEAS 101/3C
PRESSURE TEST 8 LB / SQ. IN.	NO	NO	NO	NO	NO	NO	NO	NO
	SEEPAGE	SEEPAGE	SEEPAGE	SEEPAGE	SEEPAGE	SEEPAGE	SEEPAGE	SEEPAGE
PROOF PRESSURE TEST 25 LB/SQ. IN.	NO	NO	NO	NO	NO	NO	NO	NO
	SEEPAGE	SEEPAGE	SEEPAGE	SEEPAGE	SEEPAGE	SEEPAGE	SEEPAGE	SEEPAGE
REPEATED LOADINGS TO 40% UDL OF BOLTS PRESSURE 4.3 P.S.I.C	1000 CYCLES	1000 CYCLES	1000 CYCLES	1000 CYCLES	1000 CYCLES	10 CYCLES	10 CYCLES	10 CYCLES
	SATISFACTORY	SATISFACTORY	SATISFACTORY	SATISFACTORY	SATISFACTORY	SATISFACTORY	SATISFACTORY	SATISFACTORY
PROOF PRESSURE TEST 25 LB/SQ. IN.	NO	NO	NO	NO	NO	NO	NO	NO
	SEEPAGE	SEEPAGE	SEEPAGE	SEEPAGE	SEEPAGE	SEEPAGE	SEEPAGE	SEEPAGE
REPEATED LOADINGS TO 80% UDL OF BOLTS PRESSURE 8.3 LB/SQ. IN.	10 CYCLES	250 CYCLES	10 CYCLES	—	—	—	—	—
	SATISFACTORY	SATISFACTORY	SATISFACTORY	—	—	—	—	—
REPEATED LOADINGS TO 40% UDL LOW TEMP. PRESSURE 4.3 LB/SQ. IN.	—	—	—	—	—	—	—	1000 CYCLES SATISFACTORY -25°C TO -65°C
REPEATED LOADINGS TO 40% UDL HIGH TEMP. PRESSURE 8.2 LB/SQ. IN.	—	—	—	—	—	1000 CYCLES SATISFACTORY TEMP. +66°C TO +100°C	1000 CYCLES SATISFACTORY TEMP. +62°C TO +98°C	—
PROOF PRESSURE 25 LB/SQ. IN.	NO	NO	NO	—	—	NO	NO	NO
	SEEPAGE	SEEPAGE	SEEPAGE	—	—	SEEPAGE	SEEPAGE	SEEPAGE

ment. It was possible, however, suitably to modify the machine by extending the length of the rollers, except for the last 4 in., when the frame of the machine interfered (Fig. 22). Making the last supporting upper bearing profile identical with the top roller diameter served to "iron" the remaining 4 in., which satisfactorily followed the shape of the skin.

A special routing machine was schemed and built to cater for machining the profile, rebates and recesses in the skin panels. This provided the bare essentials, a table and longitudinal slides on which ran a cross beam carrying the router head. A vacuum table was added later.

The curve required was only slight, and this fortunately was able to be sprung flat during the routing and returned satisfactorily to shape after machining.

Manufacturing lugs were provided at intervals around the perimeter of the skin which served for holding down and the location of local templates.

The large recessed areas, outboard, in the top skin were routed, a tracer for contact with the template being also used as a skid on the top surface of the skin, to control more accurately the depth of cut (Fig. 23).

The operation was carried out by sweeping the cutter in increments from side to side, always

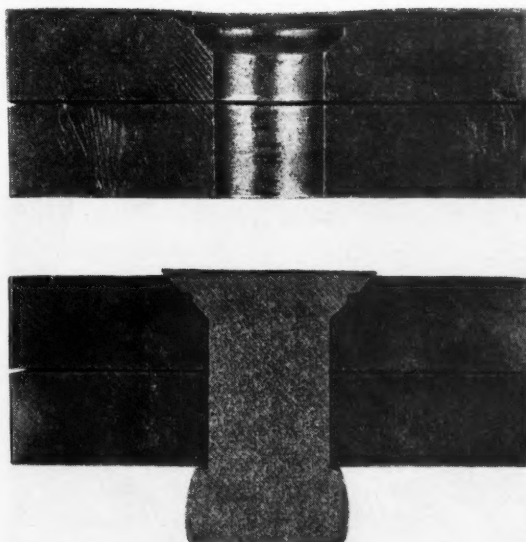


Fig. 20. Section of special rivet and countersinking

TEST REPORT ON										TEST NOTE			
RIDGED SEALING RIVETS.										Nº 257			
TEST SPECIMEN Nº	1	4	9	10	18	19	20	21	22	23	24	25	TESTS PERFORMED BY ADM 648
PRESSURE TEST TO 25 P.S.I.	S	S	S	S	S	S	S	S	S	S	S	S	
LOAD TO 40% UDL @ 7.4 P.S.I.	SEEP @ 30%	S	S	S	S	S	S	S	S	S	S	S	
1000 REPEAT LOADING TO 40% UDL @ 7.4 P.S.I.	SLEEPING	S	SEEP @ 160	S	SEEP @ 854	S	S	S	S	S	S	S	
LOAD TO 80% UDL @ 7.4 P.S.I.	SEEP @ 30%	S	SEEP @ 40%	S	SEEP @ 70%	S	S	S	S	S	S	S	
RELATIVE MOVEMENT @ 80%	007	006						0035					
10 LOADING TO 80% @ 7.4 P.S.I.		SEEP @ 10"	SEEP @ 5"	S	S	S	S	S	S	S	S	S	
LOAD TO 100% UDL @ 7.4 P.S.I.		SEEP @ 70%		SEEP @ 100%	SEEP @ 85%	S	S	S	S	S	S	S	
200 REPEAT LOADING TO 40% @ 7.4 P.S.I.		S		S			S	S		S	S	S	
ENDURANCE TEST LOADING TO 40% @ 7.4 P.S.I.					SPECIMEN BROKE AFTER 7200 CYCLES NO SEEP					SEEP AFTER 8000 CYCLES			
ULTIMATE LOAD AS % OF UDL	121%		125%	126%	122%	125%	113%	121%	125%	125%	125%	125%	
RIVET DETAILS	PLAIN CSK MAC	RIDGE CSK MAC	RIDGE CSK MBC	RIDGE CSK MAC	PLAIN CSK MAC	RIDGE CSK MAC	RIDGE CSK MAC	RIDGE CSK MBC	RIDGE CSK MBC	RIDGE CSK NM	RIDGE CSK NM	RIDGE CSK MAC	
NOMENCLATURE : S. SATISFACTORY MAC. MACHINED AFTER CLOSING. MBC. MACHINED BEFORE CLOSING NM. NOT MACHINED.													

Fig. 21. Report on special rivet test

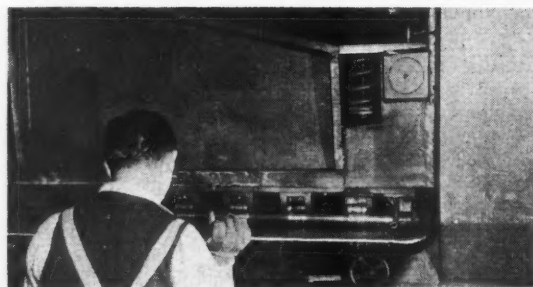


Fig. 22. Rolling the skin

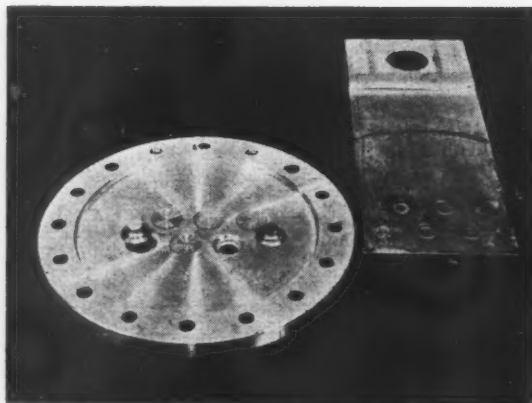


Fig. 21(a). Rivet test specimen after failure

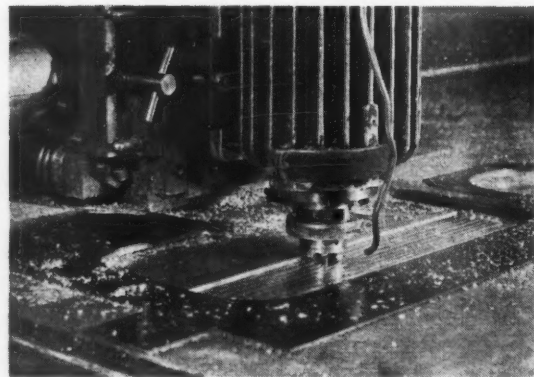


Fig. 23. Depth control skin

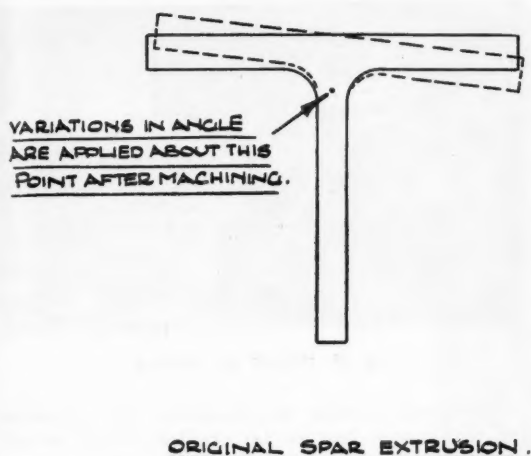


Fig. 24. Original spar extrusion

keeping metal forward of the cutter for contact with the skid, and finally to track around the perimeter of the rebate to finish and correctly radius the boundary edges. The template, of course, had to be proportionately oversize to cater for the increased diameter of the tracer. No drilling was carried out on the skin at this stage except in the manufacturing lugs.

Spar booms

The top face of each spar boom was twisted in order to follow and mate with the skin curvature. As first designed they were to be made from 3.T Section extrusions, the top flange of each being extruded 90° , $87\frac{1}{2}^\circ$ and $85\frac{1}{2}^\circ$. This was a convenient compromise to the twist required on each spar boom, i.e. Spar No. 3 — 90° , Spars Nos. 2 and 4 — $87\frac{1}{2}^\circ$, and Spars Nos. 1 and 5 — $85\frac{1}{2}^\circ$ (Fig. 24).

The point of bend selected did not go a long way to facilitate the operation of twisting, which was

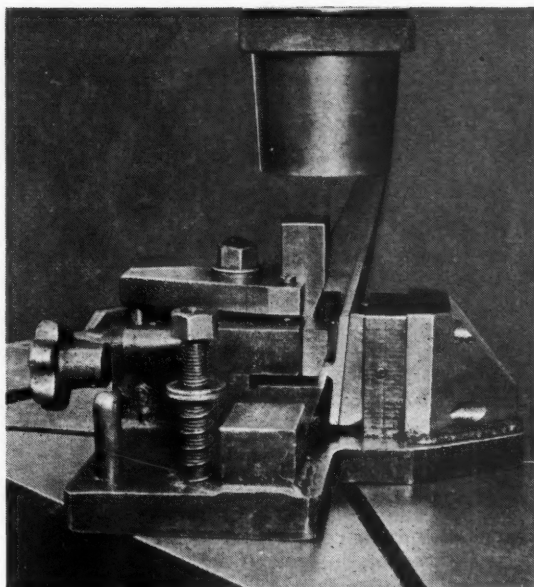


Fig. 25 (above). Twisting tool

carried out in an annealed condition, on a Mills hydraulic press, in the fixture illustrated (Fig. 25). The actual spar assembly jig was used as a reference gauge, during the development stage, the spars then being solution treated, adjusted and finally aged. Subsequently an Onsrud spar milling machine was available, with a twist milling feature on the No. 1 spindle (Fig. 26).

The extrusions were redesigned and this feature utilised, which considerably eased and practically eliminated at least one of the complications of the bending and twisting requirement, with particular emphasis on spars 1 and 5. These were bent to a 56 in. radius in a direction relative to the "T" section which was the least helpful, to the shape of a hockey stick (Fig. 27).

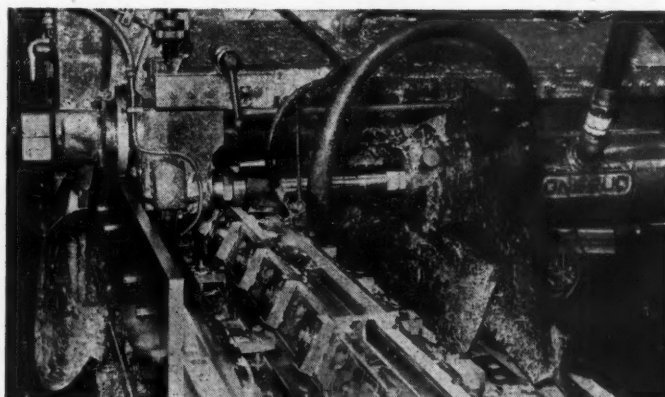


Fig. 26. Onsrud spar mill

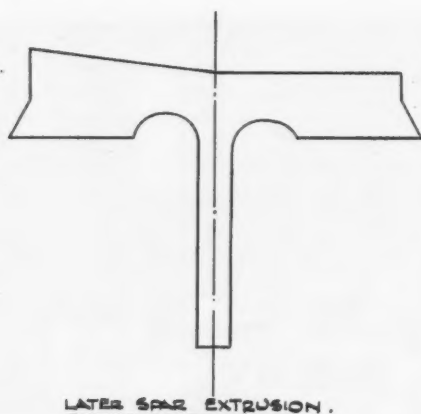


Fig. 27

Bending the 56 in. radius to the "hockey stick" shape was further complicated by another rise in a vertical direction, in order to fit the camber of the inside of the skin as it followed around from the leading edge to approximately the wing centre line. This was carried out on a Hufford A.46 (Fig. 28).

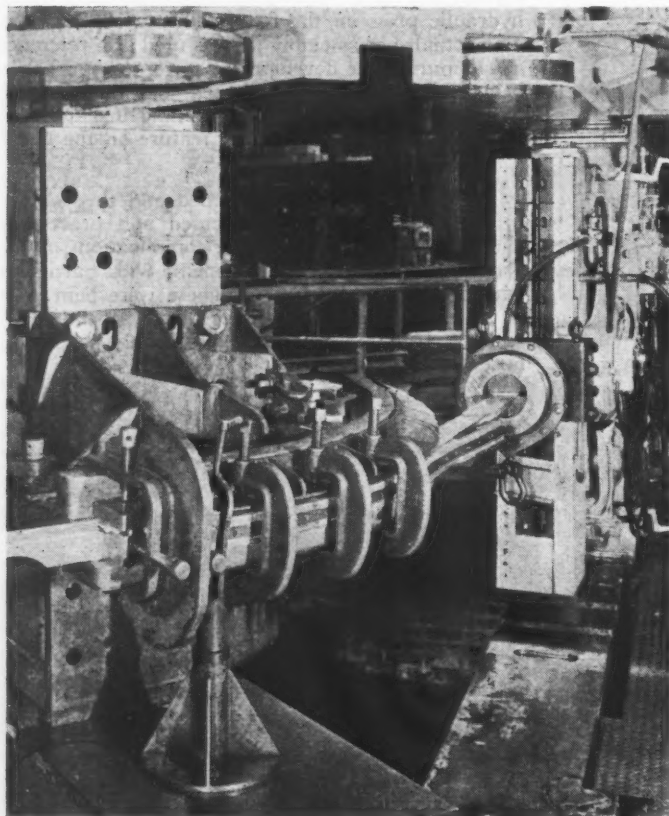


Fig. 28. Bending spar 1 to radius

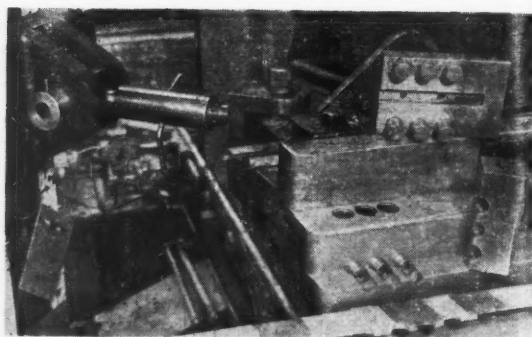


Fig. 29. Method of clamping

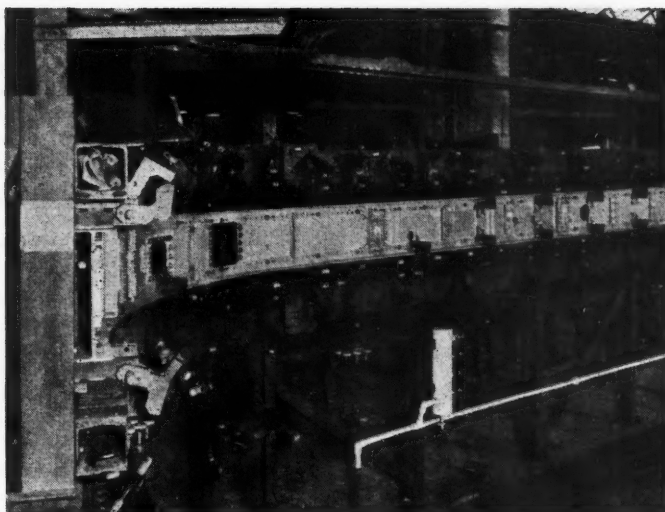
Here again further complications were apparent for the flanges had to be profiled, which would create considerable variation in cross-sectional area; if profiled after bending the release of metal would most likely disturb the "set", and the spar was much too long to be gripped at its extremities.

The decision was made to profile the flanges from the commencement of the bend to the outboard end, to size. To leave from the commencement of the bend, to the inboard end, of uniform thickness, except at the commencement of the bend, in the surplus metal on the three flanges, three scallops should be cut in each of the three flanges, to engage with pegs of a removable clamp (Fig. 29).

The former was mounted on the die bolster and the free end was connected by a substantial link to the free end jaw of the Hufford, in order to restrain the tool and component as the bent end was wrapped and stretched by the opposite jaw.

A snake was used during the forming to support the unsupported flange of the section which was protruding from the tool, and the springback of the

Fig. 30. No. 1 spar boom assembly



component after the first wrap was such that a second solution treatment had to be given, with a further set-up in the machine and a final wrap and stretch.

This was followed by adjusting the long length of the outboard end to correct the distortion caused by the heat treatment, within six hours after being taken from the bath.

Spar assembly

The spar booms are located in their individual assembly jigs together with their various attachments, the inside skin line being carefully taken care of, and all holes, in the way of the diagonals and bracing members drilled and reamed and, with fitting bolts, bolted together. The bolts are not locked, as the whole assembly has to be dismantled later (Fig. 30).

Wing box assembly

Stage 1 — 1st assembly

The spars are located in a vertical assembly jig and the ribs, undercarriage brackets, and other structure assembled, all holes being reamed, but assembly being only with fitted bolts and without sealant. Each skin is then offered up in turn for drilling and reaming of all rivet and bolt holes (Fig. 31).

Stage 2 — skin riveting

Next the wing structure is completely dismantled. The wing components are kept as a set, and any finishing, e.g. countersinking and deburring is carried out. The skins and elements of structure to be riveted to the skin are then thoroughly cleaned, the

matting surfaces coated with sealant and the components riveted up in a special riveting machine.

It was decided that any attempt at positioning either the skin in suspension, or a strong enough squeeze riveter in suspension, over a rivet head, would be quite inefficient, and the machine illustrated (Fig. 32) provided vertically balanced moving platforms with 6 ft. of vertical travel \times 18 in. of horizontal travel for the dolly and the hold-up tool, and followed the curvature of the skin.

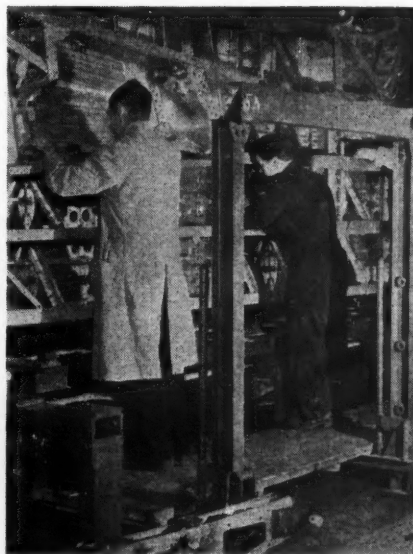


Fig. 31. Vertical assembly

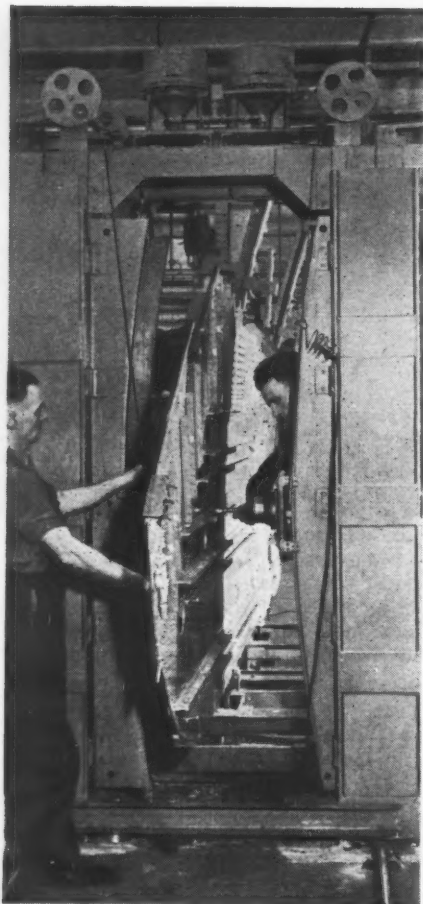


Fig. 32. Riveting main wing skin

An operator on the head side inserts the rivet and places the "hold-up tool", and the operator on the panned side "draws up" and squeezes. This can be carried out in any rivet over an area 72 in. \times 18 in., after which the skin may be moved into the next required position.

The platforms are balanced and may be easily moved up or down by hand.

Stage 3 — final box assembly

The bottom skin component, with all its attachments sealed and riveted, is placed in a horizontal assembly jig which locates all essential points and maintains the wing skin contour. Spar and rib vertical members are then attached and the top skin with its attachments lowered into position. The internal attachments are then made, working progressively outwards from the centre (Fig. 33).

It is during this stage that the amount of work necessary inside the structure has to be kept to a minimum, since the gap for access is narrow, and through this the operators have to reach locations for the final attachment bolts. To provide the maximum space possible, the booms of the front and rear spars are left off until all the internal work is completed. The final attachment of these spar booms is carried out by means of a special portable squeeze riveter (Fig. 34).

At this stage the tank unit is complete and is pressure tested.

The important feature of this stage of assembly is that no drilling or reaming is carried out, with no danger of swarf collecting in the tank or being picked up by the sealant.

Stage 4 — attachment of leading and trailing edge structures

The attachment of the leading edge and trailing edge structures is carried out in a further jig. These structures are conventional.

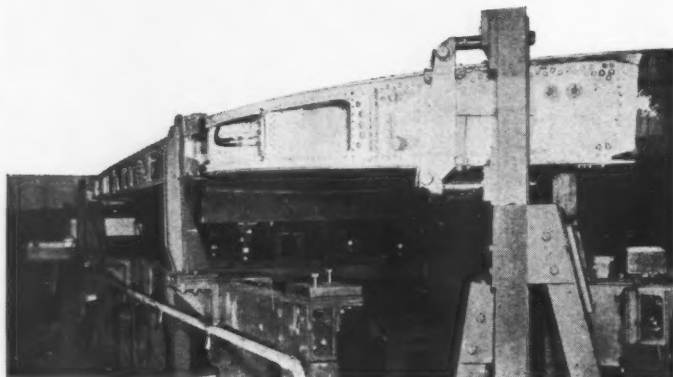
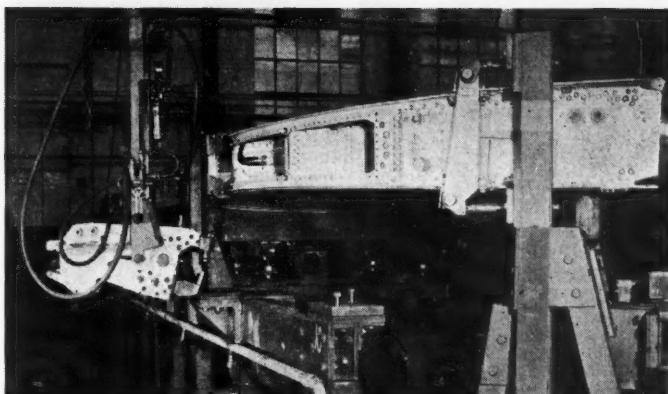


Fig. 33. Horizontal assembly

Fig. 34. Horizontal assembly and portable riveter



Wing joint

The joint for marrying the port and starboard wings together at the aircraft centre line is carried out by the provision of suitable packings of Dural strip on the abutting edges of the top and bottom skins at the centre line. These are machined to follow the aerofoil curvature, but in a horizontal plane while the wing is lying in its natural flying position at the 2° anhedral angle. This provides a parallel landing at the inboard end of each wing to accommodate the insertion of the wing centre rib and straight across doubling plates on the outer surfaces which make the joint.

The present method of machining the packings requires a special purpose machine tool of our own design and construction. The completely assembled wing box is located in its true position.

The path of the cutter to machine the packings is controlled from a cam by a hydraulic copying attachment. This machines the packings on the top and bottom surfaces of each skin, and also machines the skin edges to provide the correct gap.

An interim method pending the arrival of the special machine may be of interest. This consisted of securing the packings to a master rib and ball

milling the mating surfaces, copying from models moulded from the actual wing surfaces themselves, of each separate wing.

Wing marry-up

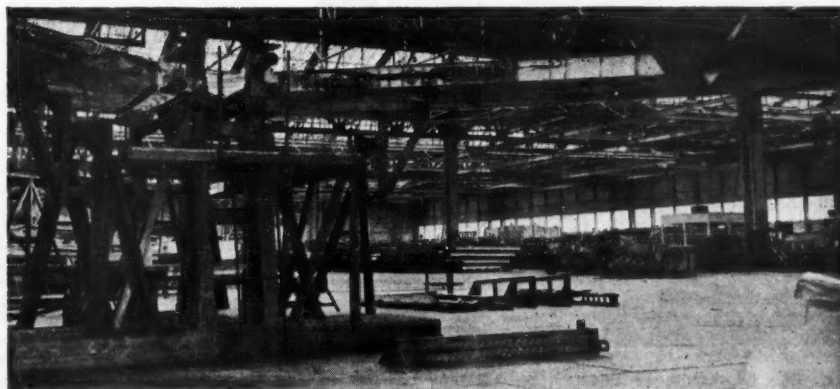
The marrying jig takes care of the port and starboard wings located by their own wing to fuselage pick-ups, in which position the wing centre rib is inserted and the drilling and reaming for the bolts through the butt straps, skin edges, packings and rib is carried out (Figs. 35 and 36). The wing to fuselage skin angles are also drilled at this stage with a drill jig gate to obtain interchangeability.

Machined items

Machined items were not unduly complex, the wing centre rib being the largest in the wings. A representative collection is shown in Fig. 37.

Owing to the necessity for weight consideration, die stampings could do little to avoid machining all over, draft angles having to be removed and small fillet radii required usually being too small to forge satisfactorily. The main gain was in obtaining some external profiles to shape and the elimination of the "hogging" surplus metal, plus of course obtaining the correct grain flow.

Fig. 35. Marrying



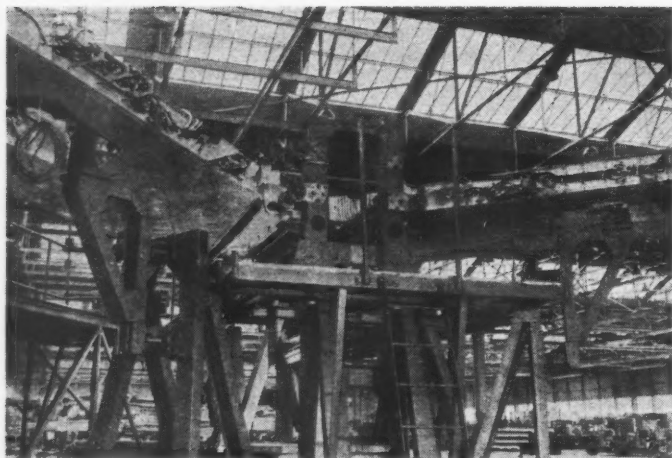


Fig. 36. Marring

The wing centre rib (A) is made from a solid billet and all the pocketing and internal surfaces machined by routing, the external profile surfaces being machined on a Hydrotel. Generally a much larger amount of double curvature machining was introduced by reason of flanges, etc., fitting directly to the skin surfaces, and consequently due to weight saving considerations, allied surfaces had to follow similar paths.

The wing centre rib was not taken up as a die stamping owing to the cost of the dies, uncertainty of quantity and the fast rate of metal removal by the router.

The main undercarriage bracket (B) as a die forging was well worth while compared with machining from solid. Machining was fairly straightforward, and it might be of interest to mention that boring the S.99 steel bearing cap *in situ* with the light alloy bracket, using a carbide tool, presented no difficulty, approximately .0005 in. ovality being evident at the cut interruption on the joint face.

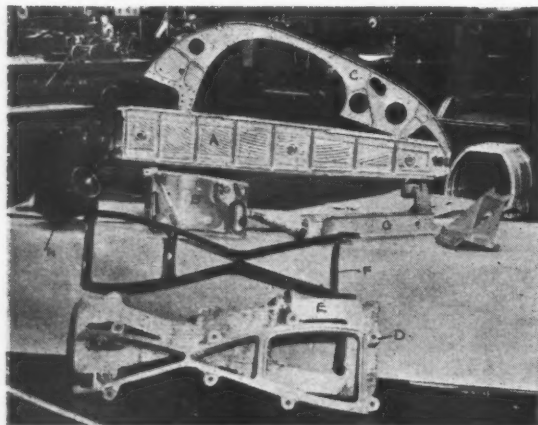


Fig. 37. Representative selection of machined components

To divert for a moment from the wing box, the following items are worth mentioning:

A half-frame (C) is machined from a solid forged billet in the "as forged" condition, roughed, heat treated, semi-finished and finished. Distortion of approximately 1/8 was satisfactorily machined out.

Component (D) set quite a problem, consisting of double curvature over 90% of its surface, and can be seen as finally a rather frail workpiece in relation to its overall size.

The development forging (E) appears to be unduly massive, but this had to be assessed in a hurry and allowance was made for probable and unknown distortion.

The production forging (F) is a recent attempt by High Duty Alloys Ltd. to press this component to finished size (Fig. 38). A die closure tolerance of -.000 in +.030 in. has been allowed, and the prospect of a satisfactory conclusion is regarded with optimism.

Component (G) is in S.99 Steel, 85 tons tensile, and tapers down to a finished thickness of .05 in at the tail end.

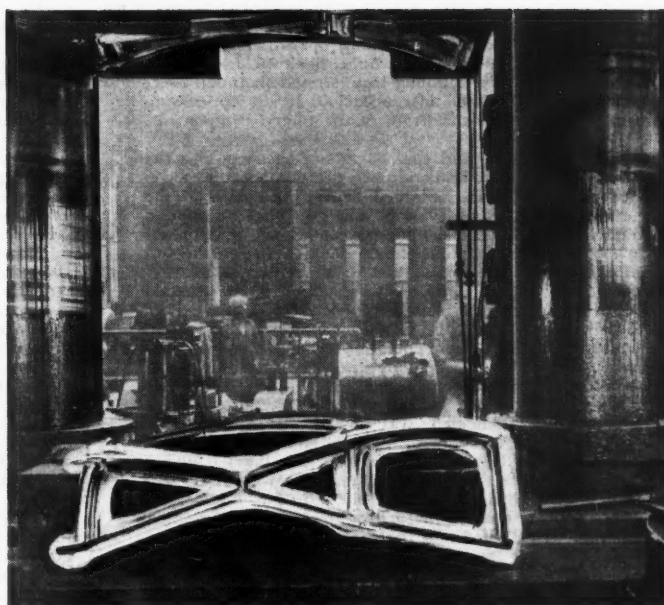
Component (H), a bearing housing fabricated by welding under rigid control, is in steel DTD.124 and S.92 and subsequently heat treated to 45-50 tons tensile.

Special purpose machine tools were designed and built for machining the packings on the wing joint, and for profiling the spar booms after bending to the "hockey-stick" shape.

Numerous difficulties can no doubt be as well imagined as described; such, for example, as preserving the aluminium cladding from damage during its progress through its operations, the applications of coatings of adhesive liquid envelope mixtures; sensible attention to footwear, and sometimes colourful advice and guidance by supervision being effective.

Further problems were the accurate cutting of countersinks by hand tools without damaging the

Fig. 38. Die pressing by High Duty Alloys Ltd.
(Courtesy of High Duty Alloys Ltd.)



immediate surrounding surface by either the tool or swarf, and the care required in milling any small amounts of surplus metal from the rivet heads.

In this Paper, we do not pretend or claim anything which is other than orthodox. It is a story of facts related to a typical aircraft problem, which is told unvarnished as far as security regulations will permit.

Before concluding we would like to express our appreciation of the excellent spirit of co-operation which exists throughout the aircraft industry and, finally, we would like to thank the Ministry of Supply, the Air Ministry and The English Electric Co. Ltd., for their permission to prepare and present this Paper.

REPORT AND DISCUSSION

Chairman: J. B. TURNER, M.I.Prod.E.

THE Chairman said that between them the Authors had produced a supersonic wing using largely existing equipment and metals. They claimed that close liaison had made this possible but he thought they were modest in not also claiming the ingenuity without which no amount of liaison would have made it possible. They were closely tied by security on the project and he hoped they would be forgiven if they could not answer all the questions asked.

Mr. Bradford confirmed that usually they were not free to discuss details of new aircraft until they were in service with the R.A.F. He expressed appreciation to the Ministry of Supply for permitting the Paper to be presented.

Mr. Taylor added to his Paper the comment that they had omitted to mention the great responsibility which fell on the Inspection Department and the Chief Inspector of the factory in a project of this nature.

Mr. H. A. Chambers, M.I.Prod.E. (General Manager, The Rockwell Machine Tool Co. Ltd.), opening the discussion, said it would be agreed that in common with all other pilot aircraft, this aircraft, which had been so ably described by the Authors, had produced machining and tooling problems such as no other engineering project had required. The production engineer had faced up to these problems magnificently. A few years ago the problems were produced by designers and were thought to be insoluble, but as time had passed they had all been ably solved. The description of the P1 and the description given in the previous Session by Mr. Burnard indicated what he was trying to say.

Mr. Chambers did not know what the tool maker and the production engineer would do when the fighter aircraft ceased to be required. No doubt they would be disappointed, because it had given them a great fund of knowledge and research.

In addition to the tooling and machining requirements, this aircraft had required deep research into sealing problems. Neither he nor many present knew much about those problems, but they would provoke considerable discussion.

He thought they should look carefully at the most accurate forgings which had been produced; to his knowledge, it was the first time they had been produced so accurately and with such a minimum amount of machining. Surely this was one of the ways in which these difficult aircraft component problems could be solved.

He noticed that the wing panels were all fabricated, and he was sure that the Authors would agree that this was a good subject for integral construction, which might be debated. There seemed to be an absence of stretch forming in the production of the aircraft. Possibly that was due to the type of aircraft, but from some of the components he had seen it appeared that stretch forming could be considered as an improvement in some respects, particularly for leading and trailing edges.

He thanked the Authors for their able description of a wonderful machine and he hoped that the few suggestions which he had made would provoke discussion.

Mr. W. S. Hollis, B.Sc., A.F.R.Ae.S., M.I.Prod.E. (Assistant Director, Ministry of Supply), asked about the spectacle

frame produced by High Duty Alloys. Was it produced as a hot forging or did a cold coining operation follow the forging? If cold coining to final dimensions was not carried out, it might be that machining from stretch stabilised sheet could have given a closer toleranced job. It was not easy to control contraction or distortion of die forged components.

Mr. Taylor, in reply, said this was a hot pressing. For the prototypes they had to make a quick decision because it was wanted in a hurry. He obtained bent $2\frac{1}{2}$ in. plate to the shape required in side elevation, and got what he wanted in four weeks. The die sinking was enormous, and manufacturing lugs to locate and clamp the job had to be left on all round; the die sinking ran to about 400 hours.

After discussing the matter with the firm, it was decided that acceptable limits to suit die forging could be devised. If there were errors in the forging, moreover, they might be consistent errors which could be accommodated. They decided to adopt this method; the whole pressing was pressed to size on a 400 ton press by High Duty Alloys, the outer and inner surface — the whole of the profile. The flange, which he indicated, was down to .1 in. The only machining of the component was the channels, which he would like design to take out, and the rear lugs; it would cost about 4 lb. in weight. The remainder was as forged, and it was brought down to -.000 in. + 0.12 in. die closure.

Asked by **Mr. Hollis** whether he thought cold coining would help, **Mr. Taylor** said that because they had to press it so close to size they did not get a great deal of spew. One of the points for which they had to cater in the design of these dies was shrinkage. The component which he indicated was +.09 in. in length. The work was done at 400°C and it did not contract as much as had been hoped. Since then a different temperature had been used; it was not stamped but pressed hot, and instead of being .09 in. plus, it was .04 in. minus in length. He was trying to achieve $\pm .02$ in. by temperature control. Cold coining to be any use would have to take place after heat treatment, which would obviously be a very protracted and expensive development.

Mr. L. J. Bolton (*Production Superintendent (Hydraulics) Sperry Gyroscope Co. Ltd.*) asked why the rig was so high from the ground. Were there subsequent operations underneath or was it because of the undercarriage?

Mr. Taylor said this was a very good question. If they were to erect it at all, they might as well erect it high, because they did not know how they would be placed subsequently. The undercarriage was fitted at that stage. The original rig they designed was built rather low, but operators who were drilling upwards took a dim view of it. In addition, trucks were being driven about the shop. When the rig was high it was more free from accidental damage. There was no particular reason for the height, however; it had to be built, so they built it high.

Mr. Bradford added that they must clear the undercarriage retractors and all the hydraulic systems. With only a few inches from the bottom of the wheels to the floor, the minimum height was already determined.

Mr. A. J. C. Smith, A.M.I.Mech.E., A.F.R.Ae.S. (*Development Engineer, The Fairey Aviation Co. Ltd.*), asked whether the Authors had developed the method of tank sealing entirely by themselves, or whether they had sought the experience of other people. The Americans, for example, sealed by injecting, or filleting, or fill and drain, and in this country wet assemblies were used. In his Company they tended towards slushing under pressure. The method used by the Authors was interesting, but it savoured of belt, braces and a spare pair of trousers. Had they reviewed all the various methods and then decided which was the best? It seemed a rather heavy and complex system to him, and they were using three methods where one should do.

Mr. Bradford, in reply, said those who had seen the aircraft at Farnborough would know that the engines were in the fuselage. It would, therefore, be very serious to have a leak anywhere in that area of the tank, above or below the

engine. Secondly, there were many items of equipment in the wing — non-return valves, recuperators, fuel gauges and so on. This obviated the use of slushing.

They had been in close contact with a number of sealing manufacturers — B.B. Chemical Co., Fireproof Tanks Ltd., and various rubber or sealing companies — who had helped them considerably. Before the P1 was started, too, they had five years' or more experience on the development of integral tanks and they were convinced that they could not rely on any one form of sealing, however good, but that it must be duplicated. The Americans would run a groove round a corner joint and fill it all the way round the corner from a pressure tapping. They forced the sealant into the groove and blanked off the approaches to the corners. This was a good method, but it was never under pressure after the first application and curing of the sealant and it did not necessarily provide for distortion of the corners. He felt that it was not enough; the whole structure would deflect, and must still remain leakproof. On the subject of special sealing rivets, **Mr. Taylor** said the ideas were mainly developed by themselves. They had another insurance scheme, in which people might be interested, by which the rivets did not go right through but were buried in the skin. This took about three times as long as the orthodox ridged rivet and it had not so far been used because of the excellent results otherwise obtained.

Mr. Taylor was asked how the groove was cut and he explained by means of a sketch (Fig. A).

A small "windy" drill was first used, with a small suitable milling or routing cutter and pushed around by hand, the bottom of the hole controlling the depth position and the shank of the cutter the diameter.

This method took too long and a second tool was made, in which a small "banana" shaped cutter was made to rotate outwards by pressure from a link which in turn was compressed by a special nut which the operator could apply as a feed. This cut grooves in seven seconds per hole.

The mating parts were then located together and a rivet placed in position, a shroud or bush placed over the protruding rivet stalk and a punch placed in the shroud on top of the rivet and this protruded the correct amount equal to the volume of metal required to be displaced to fill the groove.

It was necessary to permit the escape of air and this was done by grooving the rivets. The punch was then squeezed until flush with the shroud, when it might be safely assumed that the displaced metal had filled the groove.

This operation was advisedly carried out under the supervision of an independent inspector; if the punch went down, the metal must go somewhere.

Mr. W. Edwards, M.I.Prod.E. (*Senior Project Engineer, The De Havilland Aircraft Co. Ltd.*), congratulated the Authors on the forging which they got 99.9% correct, but said he would feel disturbed if he could not go back to the Design Office and ask them to change a dimension to one .04 in. less in order to get a 100% job. Had the Drawing Office used such a dimension in the first place, they would have achieved that end.

Mr. Taylor replied that he had the designers on his side; it was the Chief Inspector who required to be covered with suitable stated tolerance which would also permit satisfactory building.

Mr. Edwards suggested that the Design Office should be asked to rub out that dimension and to use another. In other words, to bring the drawings into line with the job being produced.

Mr. Taylor replied that they were prepared to give him almost anything he wanted.

Mr. C. P. Adams, A.M.I.Prod.E. (*Production Manager (Helicopters) Bristol Aircraft Ltd.*), asked whether the blind riveting which **Mr. Taylor** had described was acceptable to the Design Department and what were the inspection requirements in relation to this type of rivet.

Mr. Taylor replied that he had spent some time developing it; the $\frac{1}{4}$ in. or $\frac{3}{8}$ in. rivets were pretty good. The first

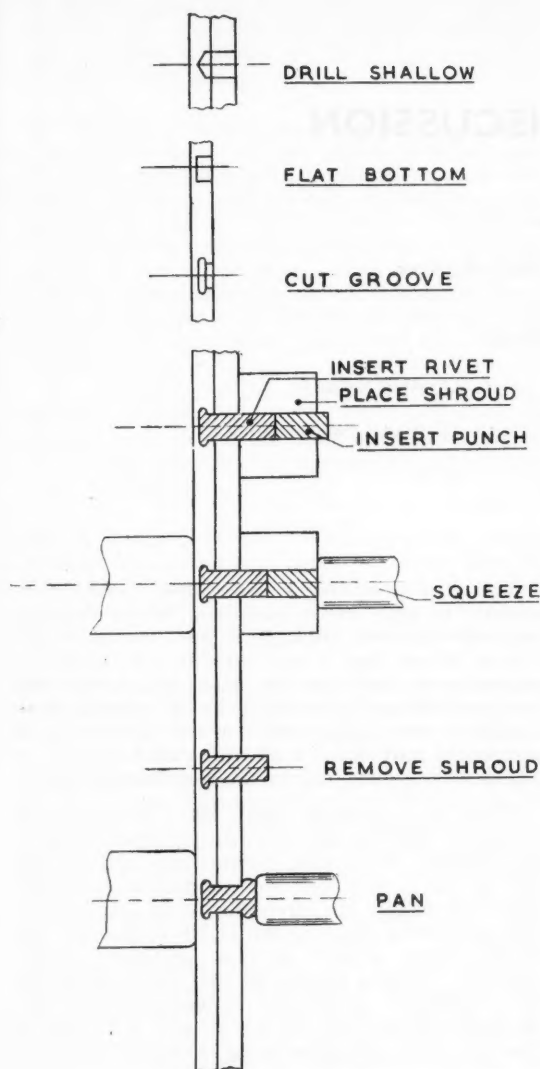


Fig. A.

method he had described involved many operations but the second which was used, was simple — drill, countersink the hole, put the rivet in, squeeze it in place. There could be further development, and he thought there could be a use for it. With the $\frac{1}{8}$ in. rivets he tended to get more work hardening, and when panning sometimes they split. He had thought of using a heated punch. It was all right for L37 rivets, but on too soft ones it seemed to set up too much friction and would not flow. The method had been produced as an insurance and had been patented, but he was prepared to help anyone who was interested in it.

Mr. E. F. Gilberthorpe, A.M.I.Mech.E., M.I.Prod.E., A.M.B.I.M., (Manager, Project Engineering, Bristol Aircraft Ltd.), asked the Authors to indicate the considerations which led them apparently to reject integral construction for the prototype.

Mr. Bradford replied that this was a big subject. At the time the prototype was on the board, the material was not available for any large integrally stiffened panels. The sheet described in the Paper was the largest available from

any manufacturer. Four years ago, Mr. Bradford had carried out an investigation into a form of integral panel, and illustrated its shape on the blackboard and by showing a slide. He stated that this skin component was to be machined out of a $2\frac{1}{2}$ in. thick slab, leaving spar, stringer sections and rib flanges as part of the skin. This was roughly half the width of the tank and at this thickness of slab and length required for the wing the billet of raw material would be 2,000 lb. Four years ago the British Aluminium Co. said they could make one or two such billets, but they could not consider at that time a large order. Since then the billet size had increased, and no doubt material of the size necessary could be made available. He believed that an integrally stiffened panel in the real sense had members crossing one another, not in one direction only. One of the previous speakers had mentioned 80% scrap, but in this case it would be nearly 90% machined away as scrap.

With this form of construction, the method of assembling the wing unit would be completely changed. Since access through the front and rear spars was so limited, and reduced still further by the inclusion of the spar flanges in the skins, it would be necessary to join each section of the wing longitudinally at the maximum thickness. By far the more important considerations on this subject were the manner in which the parts were to be manufactured, the type of machines to do this work, and the equipment necessary to correct or obtain the curvature. With a skin panel arranged as for the P1, the inconsistent cross-sectional area stretch-levelling was out of the question, and in Mr. Bradford's opinion hot forming was the only method by which a complex panel could either be manufactured or corrected.

Mr. Taylor asked whether it was sensible to go for integral construction. If it were a question of saving every ounce of weight that was a different matter, but would they not get what they wanted more quickly than by splitting them into smaller pieces? They would have to go over the skin two or three times to break it down, solution treat it, semi-finish and finish it. What would the distortion be over a component of that size? The whole scheme might eventually be abortive. There was a case for adopting this method if they were treating the scheme specially as a research aeroplane or as a civil job, but in a case like this, if they wanted it at all it was wanted quickly, and they would not get it quickly that way, without prohibitive enormous capital investment for very large specialised machine tools.

Mr. Bradford said that the shape of the wing was such that they could not hold one end and level it by stretching. If they cut 75% of the inner surface of the skin away, they would get very bad distortion on the opposite unmachined surface, which they could not possibly correct, other than by hot forming.

In reply to a comment that lack of interchangeability of wings was surely a bad design feature **Mr. Bradford** said that he had not meant complete lack of interchangeability. It was expected that in service interchangeability between port and starboard wings might be difficult. Interchangeability between wings and fuselage was easily possible, and though the wings were joined together on a mobile assembly rig with the intention of obtaining the centre-line joint with each wing in a relaxed state, that is with the weight amply supported at all main positions, they still felt the actual alignment for marrying up should be done in the factory. They thought that the equipment necessary to permit the R.A.F. to do this work was completely unnecessary and after all, all that was wanted was a pair of matched wings.

The **Chairman** thanked the Authors for their excellent Paper. They must almost have lived together to discuss the scheme before issuing drawings. It showed what could be done by these methods. The Authors had machined the wing with relatively simple manufacturing techniques and without involving a lot of capital equipment. He asked members to show their appreciation of the Paper in the usual way.

The Conference then adjourned.

COMBINED DISCUSSION

Chairman :

S. P. WOODLEY, M.B.E., M.I.Prod.E.

On the platform :

BOYD K. BUCEY

L. G. BURNARD

F. BRADFORD

G. H. TAYLOR

THE **Chairman** said there had been a departure from the procedure previously adopted, in that instead of the final lecture Session there was to be an open forum.

The last Session's discussion had been slow to start and on this occasion, therefore, he would, if necessary, nominate volunteers. A number of people had so far made no contribution, and the whole reason for the Conference was, first, to listen to the Papers; secondly, to meet and chat; and thirdly, to disseminate information. He, therefore, hoped that the discussion need not necessarily be confined strictly to the Papers; it would first deal with any questions which the lecturers had left unanswered and would then perhaps be of a more general nature.

Mr. J. Glennie, A.M.I.Prod.E. (*Production Manager (Rocket Motors), Bristol Aircraft Ltd.*), opening the discussion, said he had noticed from Mr. Bucey's Paper that very little mention was made of power spinning equipment and its development, although the Paper said: "High strength sheet materials can be formed into parabolic, conic, hemispheric and other shapes from one single piece". A great deal had been written in technical journals about the potentialities of these machines, commonly known as power spinning and flow turning lathes. The United States had undoubtedly been first in the field in introducing these machines, closely followed by one or two aircraft companies in Britain. One of these pioneers, Bristol Aircraft Ltd., had done a lot of development work in this direction with a certain amount of success, particularly in power spinning in producing component parts of conical shapes. Of course, there was nothing new in the spinning of metals, but these machines were primarily designed for the moving of metal rather than the spinning, and to produce component parts as required for aircraft and guided missiles it was essential to develop

a method of producing a thin walled cylinder consistently in high tensile materials. As yet this had not been achieved, although it was claimed by the United States that it was possible. It would be interesting to hear from Mr. Bucey whether he had any later information in this field and whether these machines were being used for the production of component parts for aircraft and guided missiles, or whether they were still in the development phase.

There was a question which Mr. Glennie wanted to put to Mr. Burnard. He had informed them of the extensive use of mist coolants with cutting tools and of the advantages over normal coolants. He agreed about this, but surely the use of mist coolants had an adverse effect on the health of the operator or any other persons in close proximity to the machine? It was understood that this method had been banned by local health authorities. Would Mr. Burnard confirm that this was so and, if it were so, how were these difficulties being overcome?

Mr. Bucey, in reply, said that precision power spinning was still much in the developmental stage. Most companies were using the machines which Mr. Glennie had mentioned, which were makeshift equipment. Boeing had had parts spun for them for missile tank ends and one company had recently designed and were now building two or three machines for the industry which would be capable of spinning high tensile steel in the range of $\frac{1}{2}$ in. and which would be capable of forging the material with a thin wall in the centre and a thick edge. These machines were scheduled to be built a year from now, but the work generally was still in the developmental stage.

Mr. Glennie, asked what were the tolerances to which these machines could produce, chiefly for parallel tubes.

Mr. Bucey replied that the machine which was being designed and which he had described would not make a tube; it would be more for a conical, rounded, domed end.

Mr. Burnard said that they had had no trouble with mist coolants from the health point of view. With mist spray as applied to the router very little coolant was used; perhaps only a pint a day was necessary to feed all the mist required to keep a cutter from smearing. It was atomised by air pressure through a very small tube. When it reached the cutter it was immediately converted to liquid. There was very little mist in the air that the operator could breathe, and as a consequence they had had no trouble.

He did not know the method Mr. Glennie had used, but certainly that used by Mr. Burnard did not produce a cloud that the operator could inhale. If Mr. Glennie was further interested, he was welcome to see for himself.

Mr. J. Longley (*Chief Project Engineer, Bristol Aircraft Ltd.*) asked Mr. Bucey to explain how the American aircraft manufacturers phased into their production line the essential modifications and design changes, while still maintaining delivery promises.

Mr. Bucey replied that the American manufacturers had their problems, just as had the British manufacturers. The theory — it never worked in practice — was that they tried to schedule that all changes would take place at a certain point in production; in other words, between 50 and 51 or between 100 and 101. Unfortunately, there were too many mandatory changes which had to come into effect almost immediately. The Company used a Change Board; the Chairman was a man from the production planning group in the factory and there were representatives from industrial engineering, scheduling, tooling, material and purchasing. They considered the proposed change to the best of their ability and considered how many parts would be involved, as well as when the drawings would be released. Each member of the Board studied the problems and made a commitment for his department, and from the combined commitments the activity date or airplane number was established. It became very complicated, and there were so many changes that, on the B52, for nearly a year two Change Boards were meeting continually. To make it more complicated, on an aircraft where they had both a civil and a military version there was a Change Board for both, and these had to keep together because they might be affected by each other's changes.

They had many headaches, but the system worked fairly well and they were quite successful in remaining on schedule.

Mr. L. J. Bolton (*Production Superintendent (Hydraulics), Sperry Gyroscope Co. Ltd.*) said they were using the mist lubricant and operators in the

machine shop around machines using this lubricant had experienced some discomfort. Extractor nozzles had been fitted adjacent to the other side of the tool from where the mist coolant impinged and as a result there was now virtually no mist in the shop. This had dealt with the problem satisfactorily. If they were to use this system on a larger scale, as seemed possible, using mist lubricant on most machines, they would probably fit a common extractor and condensing vanes to reclaim the coolant, because they used more coolant than Mr. Burnard had suggested; on one particular milling operation, they were using up to half-a-gallon a day.

Mr. Burnard, in reply, said that the containers they had designed contained only half-a-pint of coolant in small cups like those of a spray gun. The nozzle was very small. They were using the mist not as a coolant but as a lubricant, attempting to prevent cutter smear. As long as the teeth were lubricated, there was no pick-up or smear. The minimum of lubricant was used; the less one used, the better were the results from the health point of view. The film which he had shown the previous day had been cut or it would have shown the mist lubricants being used. If members saw it in operation they would agree that there was very little lubricant mist in the air around the tool. His advice to Mr. Bolton was to cut down the amount of lubricant.

Mr. B. L. Johnson (*Technical Representative, London and Southern Area, Wadkin Ltd.*) said that his firm supplied an adjusting screw on the apparatus for the mist lubricant which could be set so that the amount of oil and water being used was very small indeed. If vaporisation took place, it was recommended that the proportion of water be increased to equal that of the oil and then, by use of the adjusting screw, a fine jet could be produced, giving little or no vaporisation.

Not long ago, however, not far from Sperry's, he had visited a factory where there had been complaints about the volume of oil mist. The machine was not a router but a high-speed milling machine. The man in charge set the machine and the mist lubricant going and the whole shop was blotted out by an oil mist, with great clouds everywhere. The cause was a leaky washer — a fault in the apparatus.

Recently a welfare officer from one of the firms on the South Coast had been perturbed about the effect of oil mist on the operators. He had applied to the manufacturers of the oil mist, in this case, Fletcher and Miller Ltd., and had been assured by them that there was nothing toxic in their product. The same lubricant was used by Sperry's. The only comment he would make was that in a closed space the tendency was to make one feel rather clogged at the throat and chest if the mist were used heavily. As Mr. Burnard had said, that was due to using too much of the mist.

Mr. Bolton commented that they had been through the stages of experimenting with amounts of lubricant and air in various proportions for vapour mist, they

had valves to control it, and they had now reached the stage where they thought they knew the right amount to use. If they cut it down more they had reduced cutter life. That was why they thought it worthwhile to fit the extractor to take away the excess. Incidentally, they were not using a Fletcher Miller's coolant, but D.T.D.585 hydraulic fluid, as he had mentioned in a previous Session.

Mr. P. H. C. Waddington, A.M.I.Prod.E. (*Chief of Standardisation Section, The English Electric Co. Ltd. (G.W. Division)*), asked Mr. Bucey what provision was made in the United States for the utilisation of components which could not be called standard, but could crop up again, especially with relation to the tooling of such components. Often by a slight modification the expenditure on completely new tooling could be avoided and eventually a new standard created.

Mr. Bucey, in reply, said that if a part or an assembly were rejected, it was immediately sent to a Material Review Board composed of engineering and inspection representatives and occasionally a Services representative. They did not always have a representative from the Air Force. They determined whether this part could be used in an aeroplane, and in many cases it could. Pieces of paper to cover the variation from the drawing were attached to the drawing and a record was kept to show that the aeroplane in question could have this part which was under-size or over-size.

Mr. Waddington said he was referring not to a component which was sub-standard to the drawing, but to a component which was not standard in the sense of being an interchangeable part. Asked by **Mr. Bucey** whether he was referring to aeroplane or missile parts, he said he was speaking, generally, about aircraft parts.

Mr. Bucey said he did not know quite how to answer the question. At Boeing, many years ago, whenever an engineer designed a simple clip or bracket which had a potential future use a drawing was put into a book, but eventually they had a stack of books the width of the lecture room and no engineer designing a new bracket would ever refer to them. In any case, it was a hopeless task to find anything.

That practice had been dropped. Obviously such things as bolts, screws and flange holes were standard size and the engineers also had a complete list of their standard tools. They were limited on such things as tube bend radii; wherever possible they had to use the standard. They also knew the diameters of all the milling products which were normally stocked and they tried to design around what was available, but that was as far as the firm were able to go.

There were a few exceptions; pulley brackets were normally made from a double extrusion. A record was kept and they had to try to use the same general shape, if possible. The engineers talked to each other

and if they had to design a similar part they would pull out the old drawing and try to use it. They would refer to this part in the parts list with a dash to show that it was similar to the other drawing, and would give the reference to the previous part. In the same way, when they redesigned a drawing and changed many parts, they stated which parts were not changed in order that the same tools, with perhaps slight modifications, might be used.

Mr. E. F. Gilberthorpe, A.M.I.Mech.E., M.I.Prod.E., A.M.B.I.M. (*Manager, Project Engineering, Bristol Aircraft Ltd.*), asked whether he had understood Mr. Bucey to say that, apart from having a Change Board, they interrupted the production line only at fixed intervals, with obviously as long a gap as possible in between interruptions. How adamant were they about that? Would Mr. Bucey develop that? Secondly, what did Mr. Bucey mean by dinking or cookie cutter dies, referred to in his Paper?

Mr. Bucey, in reply, said he had tried to be careful in what he said about Change Boards. That was the way they liked to work in theory, but in practice they reduced the size of the increment to one aeroplane! There seemed to be so many mandatory changes which had to be introduced either for the safety of the aircraft or because the engineer wanted to cover some mistake, and as a result they had many small increments. They did everything in their power to try to work by larger blocks, but it was not always possible to do so.

The cookie cutter die was the type of die which was used "rule stock". They used cookie cutter dies or dinking dies for blanking out possibly 2040 or stainless steel 10,000 successfully. They supplemented the cookie cutter die with a male punch; they made a cookie cutter die, impressed it upon a piece of steel, cut that out and had a male punch which was securely clamped. Dies were being used by such companies as A. L. Smith to blank out 100,000 parts in 4130 steel in thicknesses of $\frac{1}{4}$ in. It was almost unbelievable that such a fragile tool could do the job, but it had become quite popular in industry in general and in the aircraft industry in particular.

Mr. J. Purcell, A.M.I.Prod.E. (*Research and Development Engineer, The College of Aeronautics*), said that Cranfield was equipped with an extensive coolants laboratory in which the mist spray method of cooling was used. The pollution of the local atmosphere was checked by a small rig which consists of a piston in a cylinder. This piston was made to reciprocate within the cylinder; the number of strokes per minute being equal to the rate of breathing of an operator. The piston displacement was equal to the volume of air inhaled by an operator. The end of the cylinder carried a gauze filter.

The equipment could be placed near an operator using mist spray equipment and an analysis of the gauze would give an indication of pollution. The equipment had psychological as well as practical value.

(In a written comment subsequent to the Conference, Mr. Purcell adds:

Tests have been made relating atmospheric pollution with cutting efficiency when using mist spray equipment. These tests showed that up to peak cutting efficiency, pollution was very little. Only if an increase in coolant was supplied beyond that point where increase in performance was recorded, was there noticeable pollution of the local atmosphere.)

Mr. Bradford commented that he had strong views about standard tools, cutter diameters as well as cutter sizes. His firm kept very close and accurate lists of standard cutter sizes in the shops and the designer would always refer to these in the drawing of a machine shop part. Wherever possible they kept to those standards and it was only in exceptional circumstances that they departed from them.

Air Vice-Marshal G. R. C. Spencer, C.B., C.B.E. (Representative, *William Jessop & Sons Ltd.*), said that when aircraft came into service in the U.K. they were often followed by a spate of modifications. He had gathered that this did not happen so much in America. Could Mr. Bucey explain how it was avoided?

Mr. Bucey, in reply, said he was afraid that the information was erroneous! The engineers did everything that was humanly possible to design the aeroplane completely equipped the first time built, but invariably the pressure of time and, possibly, the lack of experience of new materials or new type of aircraft, were bound to lead to areas where corrections were needed. In addition, particularly in military aircraft, they wanted the utmost in performance, and new potentials in performance, potentials in saving weight and in increased range were bound to lead to one improvement after another. That was one reason for all the changes which were made.

They realised, however, that these conditions would have to be drastically improved in the future. With the reduction in the number of weapons they would buy and the increased cost of these weapons, the Services would not stand for extensive modification. That was one reason for the trend, which his Paper had revealed, towards drastically increasing the ability and the strength of the manufacturing department, so that they could have a better understanding of the designer's problems and were more capable of assisting the designer in advising him on the best design from the point of view of producibility, reliability and quality standards.

He believed that there would have to be manufacturing engineers on a level which would enable them to talk across the Board to design engineers and, jointly, to determine the type of aircraft which would be built in the future, hoping drastically to reduce the modifications. He hoped that he had not implied that there was any antagonism in their relations with engineering, because they worked very closely together as a team, but they knew that manufacturing were not fully qualified to do the job and they

were doing everything they could to strengthen the manufacturing end so that they were capable of assisting engineering. They wanted their manufacturing engineers at Boeing to keep up with trends. For instance, if a design engineer wanted to use beryllium and he knew nothing about it, he would be able to call in a manufacturing or production engineer who had kept abreast of the development of beryllium and who knew the do's and don'ts about using it. This was a challenge to manufacturing.

Mr. C. P. Adams, A.M.I.Prod.E. (*Production Manager (Helicopters), Bristol Aircraft Ltd.*), asked Mr. Bucey for more information about the incentive schemes to which he had referred in the Paper under "An effective management tool". The Paper did not mention joint consultation between workers and management. Would he comment on that as practised in the Boeing Company?

Mr. Bucey replied that he hoped he had not given the wrong impression; the incentives to which he had referred were other than monetary. It was a question of the desire to do a good job and to understand where a man's work fitted into the general picture. As for joint consultation, when designing a new aeroplane they did not consult every one of their 10,000 employees on how it should be designed, but there was consultation and he could perhaps best describe it by reference to tool design.

In practically every sub-assembly jig they designed, after they had studied the problem they prepared a simple freehand illustration, a production illustration, of how they thought the jig would look. This was a piece of paper, 8½ in. × 11 in. The operation to be performed was described. The paper was circulated first to upper supervision in tooling, who made such comments as: "Remember the problem we had with such-and-such a jig? Have you allowed clearance? How will you gauge this?". No one held these sketches for more than half-a-day; if they had not time to look at them, they passed them on. The sketch then passed to the jig department for their comments; they might say that in the jig fabrication department there was a shortage of labour for a particular jig and that the design and method of assembly should be changed to where there was a surplus of labour.

Next, it went to the planner who ordered the jig, to see whether it fitted in with his planning and finally it passed to the shop which would use it. The latter began to think where they would put the jig, and this led to such comments as: "It will be very inaccessible, it will be at an awkward working height, some of the braces are in the way", and so on. The sketch was then returned to the designer, who did his best to incorporate all the suggestions made.

Prior to the release of the drawing, they called in the supervisor of the shop which would receive the tool and he had a final chance to make his comments on the changes. He was told all the bad features of the tool. Inspection, too, had the chance to make comments. The supervisor of the shop which would

receive the tool signed off the drawing. Thus, everybody had taken part in the design of the tool. When it reached the shop it might be the worst jig in the shop, but the shop would certainly make it work!

This sort of co-operation was very successful. Possibly it did not meet the question about incentives, but in that respect some companies had piece-work, although Boeing had not. A certain percentage of the profits were put aside at Boeing and paid to the supervision as a bonus *pro rata*, depending on how good a job each man had done. There were some exceptions to the *pro rata* arrangement. Up to last year, half of the bonus had to be taken in stock of the Company, to give them a personal interest in the Company, but this year it would all be taken in stock because of the need for new equipment.

Asked about joint consultation, which the **Chairman** interpreted as "labour relations with the trade unions", **Mr. Bucey** replied that every two years there were negotiations with the unions for a new contract to determine wages and other conditions, but that was about as far as they went. "We run the Company", he said. "We decide who is qualified for promotion or demotion". Every employee was graded every six months; the supervisor completed a piece of paper and called in the employee to discuss it with him, before the employee signed it. Unfortunately, because he was human, the supervisor usually did not like to tell the man about his poor qualities and tended to avoid doing so, but in general this piece of paper pretty well represented the employee's performance. The employee could appeal to the union and the Appeal Board.

Employees were rated on this piece of paper. First, they were in a salary bracket, and within that bracket they were rated A, B, C or D. Whenever demotions had to be made, as far as possible they took someone from class D, and then demoted someone from the bottom of C down to D and so on, but if possible this method was not used. There had been a strike, which had lasted a long time, but it had paid off and the management had held on to the prerogative of managing the Company.

Mr. J. W. Jones, M.Sc., F.R.Ae.S., F.I.M.A. (*Senior Lecturer, Materials and Metallurgy Section, Department of Aircraft Economics and Production, College of Aeronautics*), said he had found no reference in any of the Papers to what he regarded as the most productive of all production methods — castings. He could anticipate the immediate reply that the casting was not strong enough for the job, but that was a challenge to them to decide whether castings were inherently weak or whether they merely needed the development of methods of production. From research in the College, he subscribed to the latter view.

He asked **Mr. Bucey** whether there was any tendency to use castings in airframe construction in the United States. He had in mind, in particular, high precision and high tensile castings. Turning to **Mr. Bradford**, had castings been considered at any time in the production of the P1? If not, why not?

Mr. Bucey, in reply, said their engineering department would very much like to use castings, and engineering committees and manufacturing committees of the A.I.A. and other societies had been working with the casting industry and with the Government trying to get enough interest in the job in the casting industry. Spasmodically the industry would produce a few consistent castings, but he did not think they had yet realised the potential amount of business open to them if they developed the techniques of producing good castings. Unfortunately, the casting industry had not greatly improved for many years, and it was their inability to give consistently good castings which prevented Boeing from using them. When these castings were available he was sure they would be used, because they were needed.

Mr. Bradford, in reply, said they were using some castings in the P1, but weight, strength and reliability had always to be taken into account. One of the specimens on exhibition was supplied as a casting and for another example they had a casting as an alternative. In the latter case, the casting broke the test frame, but a welded bracket had been found to be superior. The aileron hinges were castings, but were investment castings. These had been chosen primarily because of the better strength and, most important, the surface finish. He believed that a casting was not very practical if it had to be machined all over, except in some special cases. Generally, the choice of a forging or a casting was always to minimise machining, and with steel castings it was usually necessary to machine all over to remove the scale on normal castings. The investment casting could be cadmium plated in the "as received" condition without any form of descaling or cleaning.

Mr. Taylor did not agree that casting development had not progressed. The introduction of shell moulding had led to an improvement. He showed a photograph of a specimen as a sand casting and as a shell casting. On the sand casting big pads had been left on as location pads in which location holes had been drilled. It had taken about 25 hours' die sinking at, say, £1 an hour. He had taken the matter up as a shell casting merely with the idea of finding out what they could get out of shell casting. A steel pattern plate was made, heated to about 300°C, sprayed with a parting agent and a sand and resin mixture dropped on to it. In about 5-10 seconds, the "biscuit" grew to $\frac{1}{4}$ in. thickness and was cured. This was removed and the process repeated. A "biscuit", two of which formed a mould, could be produced every two minutes by this method. After being separated, the two parts were put together and a cavity formed into which metal was poured. As the metal solidified it set fire to the biscuit, which burned away and dropped off.

No further machining had been necessary and the part had been used with satisfaction on the Mark 8 and Mark 9 Canberra.

In fact, they were using castings in their work, for example, on one of the parts of the front wheel

undercarriage. Investment castings in steel were used for the aileron hinges.

Another technique which was being developed was that of dipping a wax mould into a refractory slurry and getting it to grow into a biscuit. It would cure and could be heated. The wax melted out and left a perfect cavity. One could reckon on an average of about .002 in. error per in., which he found very useful. The only point was that with the cast material the tensile strength was about 18 tons and with die stamping it could be double that.

Mr. P. V. Brown, A.F.R.Ae.S., A.M.I.Prod.E. (*Aircraft Production Development, Ministry of Supply*), referred to the previous question by Mr. J. W. Jones, and said that he thought that with the advent of vacuum melting and vacuum casting equipment, considerable progress would be made in the near future with high strength steel castings. They hoped shortly — when the necessary plant was available—to produce a large aircraft rib close to finished size, by melting up to 600 lb. of metal in vacuum, and casting either under vacuum or in an argon atmosphere. The steel makers expected that they could obtain in castings an ultimate tensile strength of 85 tons per sq. in., with a 7% elongation. The thin webs required combined with heavy flanges were not a very good shape for casting, and although they were not over optimistic, the development offered a possible solution to the machining problem on ultra high strength steels.

He referred to a component being produced for a current aircraft in high tensile steel, similar in form to the light alloy rib exhibited by Mr. Taylor. In this case, the rough steel forging weighed over 1 ton, and it was machined down to 1,500 lb. at the forge, and finally reduced by milling down to 300 lb. at the aircraft contractor's works. Would Mr. Bucey confirm that in the United States similar components were being fabricated by welding using plate 0.1 in. to 0.15 in. thick for the webs, with heavy booms and stiffeners welded in position?

He thought that this approach, by welding and fabrication, might offer the best solution to the reduction of machining for large high strength steel fittings. He would be glad to have Mr. Bucey's views, and to know from anyone present of work being done on the subject in this country.

Mr. Bucey agreed that they were making extensive use of elements of that nature. The major bulkheads in the B52 were made up of several weldings, each at least as large as the component on exhibition. There had been trouble with some of the suppliers, however, including the Company which had been mentioned, and Boeing had had to pull out and to go over to precision forgings, which were now being used. This had put them in a spot and they had to go through five series of different bulkheads before getting back to the first production. They were now using precision forgings, machining probably only the internals and the outside face. Although they were still having a little trouble with one of the five forgings used, on the whole they were getting

beautiful forgings. It had been a tough business, but the techniques had been learned and they had agreed on tolerances and restrictions.

Six months ago Boeing had asked for another precision forging and had been told that it would take 18 months to make the die. As a consequence, they had redesigned to the welding, and that had been in production in about 12 months.

Asked why they had pulled out, Mr. Bucey said it was because of the management and not because of the technique. Boeing believed in the use of weldings. He was afraid that the length of time and the cost of getting precision forging dies was to some extent defeating the purpose of the forging press programme and was forcing them to use welding. He believed that they would be switching over to the method started in the U.K.—the use of stretched, levelled slabs and numerical control, which was faster and cheaper; one could almost buy the numerical control machine for the cost of the dies! Changes could be made almost immediately, and the method had a great potential. Probably they would use all the methods.

Mr. Taylor asked whether he understood that ultra high tensile steel was being welded, and **Mr. Brown** replied that this was so in the United States.

Mr. Taylor said he did not pretend to be an expert in the subject and asked for information about the high carbon content of the steel.

Mr. Bucey referred the question to Mr. Burnard, who had seen and could describe the steel.

Mr. Burnard said the American specification of the steel was AMS 6428 bar and rod, and AMS 6434 plate. This was an equivalent steel to SAE 4345, with an addition of vanadium so that it might be stress relieved at reasonably high temperatures without drawing the temper. It was arc welded using 5% chrome (E 502) welding rod.

He had seen the B52 bulkhead, which was about 10 ft. tall and was made up of a series of plate fittings, completely welded in a series of sub-assemblies and finally assembled and heat treated. It seemed to him a very good development to be able to make high tensile steel components in a very simple manner.

Another component he had seen there had been made by flash spot welding — a big wish-bone affair for one of the aeroplanes. It had been tailor-made. Three pieces were machined, and abutments left at the joints to aid the location and gripping in the flash butt welding machine. They were brought together in a predetermined manner as the resistance weld was being made, so that the exact dimension was achieved. They expected to get as much strength in that joint as in the parent metal. This was another method used.

Mr. Bucey commented that this was sub-contract work and that he did not know many of the details, and **Mr. Burnard** added that he had seen it at

Cleveland, used for building up a steel undercarriage component.

Mr. A. W. Menzies, M.B.E. (*Production Development Manager, Sir W. G. Armstrong Whitworth Aircraft Ltd.*), asked Mr. Taylor, in view of what Mr. Bucey had said and of the very fine precision forging of the canopy, whether he was justified in using this method, bearing in mind the cost of dies and the time.

Mr. Taylor replied that when they began such an aeroplane they sometimes had to forget economics. These copying machines cost a lot of money — £25,000 each — and a fairly high rate of production was required. Using the machine, with a better utilisation on smaller components, seemed to be worthwhile. At a rate of 400 hours — this was the time involved, going over the components three times — they could probably recover the cost, given a reasonable order.

Mr. Menzies said that knowing Mr. Taylor's capabilities he had certain doubts in his mind. If Mr. Taylor had not thought there would be a large order for the P1, would he have ordered the forging for the present quantity? He was quoting 400 hours, but, with Mr. Taylor's capabilities, that would probably have been done to 50 hours within a few months.

Mr. Taylor thought that might be done if they designed a special machine, but how long would that take? What would it cost? It might be possible to tackle the two surfaces at the same time — one cutter on one side and another working on the other side at the same time. His first reaction had been: "Do we want this at all? Cannot we design something better?"

Mr. Menzies asked what was the time taken to get the dies and, without asking what Mr. Taylor had been charged, was the cost covered on the 20 machines?

Mr. Taylor replied that it was not. It had cost a lot of money and if there were not a substantial order, or the minimum anticipated order, many horrible questions might be asked. They must always be a little bold and take a chance in these matters. In any case, supposing they made 70 machines, if they could save 400 hours that was nearly £400 per aircraft component.

In reply to a comment that these were very cheap hours, Mr. Taylor said that even at that figure, they would be well on the way to cost recovery.

Mr. Menzies did not agree with the figure of 400 hours if they were to produce so many components. That could have been cut down a lot with routing. Mr. Taylor had suggested that money did not matter, but the position was arising that it did matter.

Mr. Taylor said that fully three-dimensional routing was not available. He agreed that the component

might have been tackled in that way, but it would still have been necessary to go over it two or three times. This subject could be discussed for a long time, and in any event he had described what he had done.

Mr. H. Hainsworth, A.M.I.Mech.E., A.M.I.Prod.E. (*Engineer Main Grade, Ministry of Supply*), referred to the Green Linnet copy milling machine and the statement in paragraph 2.8 of Mr. Burnard's Paper that it was capable of removing up to 50 lb. of aluminium per minute, which was roughly 500 cu. in. per minute. Mr. Gregory, in the commentary on his film, had spoken of 100 cu. in. per minute removal. Had they achieved 500 cu. in. per minute removal, were they doing it with the 20 h.p. machine described in the Paper or was the rate of 500 cu. in. per minute a pious hope for the future?

Mr. W. S. Hollis (*Assistant Director, Ministry of Supply*) said there were two developments for the milling heads, one of 20 h.p. which gave a removal rate of 100 cu. in. per minute and one of 50 - 100 h.p. Removal was reckoned at 5 - 7 cu. in. per minute per horsepower, so that the 100 h.p. head gave 700 cu. in. min., which, with the density of light alloy at .1 lb./cu. in. resulted in 70 lb./min. The later development would be coming along in six months.

Mr. Burnard said the information had reached him from Mr. Hollis's office. When he read it he could not believe it and he telephoned Mr. Hollis, who said the figure would be 700 cu. in. but, to be on the safe side, should be given in the Paper as 500 cu. in.

Mr. W. W. W. Downing, M.I.Prod.E., A.F.R.Ae.S. (*Works Manager, Gloster Aircraft Ltd.*), asked Mr. Bucey to give an indication of the size of the design staff, plant staff, tooling staff, and so on, possibly relative to one project. Could he give an indication of the size of the project?

Mr. Bucey, in reply, said he did not wish to appear to evade the question, but it was a very difficult one to answer. There were four operating divisions in his Company, which had been reorganised 18 months ago. Some of them were complete entities, even having supersonic, transonic and subsonic wind tunnels and testing equipment. Others were the assembly lines involved in the construction of military aircraft, commercial aircraft, missiles and even small turbine engines. The works were intermixed; even engineering design was intermixed. The Seattle Division was doing work for the Wichita Division, for example. There was mutual support, with each Division helping another. It was, therefore, difficult for him to give the figures from the design standpoint, which was out of his field.

Turning to product development or manufacturing research, in the Seattle Division, about 400 people were working on developing new methods for the Transport Division and on engineering in the future. In the same Division there were probably 750 tool

designers, including their engineer aids, the draughtsmen and the clerical workers. In those two Divisions there were probably 500 tool planners and processing people. That took care of the B52, the 707 and the 135. He could go no further in answering the question, because it was difficult to divide the numbers. Indeed, it was an accounting problem to keep them straight in dealing with costs.

Mr. C. A. Burton, M.Inst.W. (*Sales Manager, Sciaky Electric Welding Machines Ltd.*), said there had been no discussion of fabrication by welding, and he believed that the Boeing Company were among the largest, if not the largest, users of resistance welding in the manufacture of air frames and in fuselage construction in America. He, therefore, wanted to direct some questions to Mr. Bucey. Could he give any indication of cost comparisons between resistance spot welding, riveting or bonded structures? Could he enlarge on any fatigue tests which had been carried out in America on stressed spot welding joints? Had anti-corrosive paints or primers been used between interfaces of 24 ST. and 25 ST. material? What were the trends in resistance welding in aircraft construction?

Mr. Bucey said he could not answer all the questions. Boeing certainly used a great deal of resistance welding. It was a method they had used since the conception of the B17, and they had been using it for so many years that it was an accepted method. Cost studies had been made, and they thought that to drill a hole and fit a rivet cost upwards of 50 cents, so that spot welding was obviously much cheaper — a fraction of that. They had no fatigue problems and he knew of no failure, although probably they had them in the B17 days. In the B17, all the wing section stiffeners and most of the fuselages were welded, and they thought that this method had a great future. They felt that with supersonic aircraft they would use a great deal of welding.

He was not aware that they were using anti-corrosive paint prior to spot welding; he knew that they did not do it in production and he was not aware of any test work.

As for future trends in resistance welding for air-frame construction, they believed that they would end with a sandwich construction. It would consist of two tapered sides, half-sections, back to back, or something like that, which would be completely spot welded. This was the greatest potential for reducing the cost of supersonic aircraft, because the braced panel using honeycomb cost 1,000 dollars a sq. ft. The production department were working hard to reduce the cost, by new equipment and techniques. They would probably have to use that method in some areas, but wherever possible they would switch over to the well-known and reliable resistance spot welding. Welding schemes were constantly being improved; the three-phase welders were a big improvement.

Mr. Bradford referred to the problem of welding 16 gauge stringers to a 14 gauge skin.

He explained that the stringers were required for stabilisation. The welding department insisted on the flange being .95 in. wide. A $\frac{1}{8}$ in. rivet of 1 in. pitch would have been adequate to attach the stringer to the skin and a .6 in. wide flange would have been enough, but .35 in. material had to be added to the stringer flange solely to permit spot welding. Looking up the A.D.A. handbook on welding and checking the slug diameter given for each gauge of material, they did not disbelieve their welding department. This was for a circular slug, however. Assuming that they must have that volume to get the right degree of weld, why could not they have a spot weld elongated the other way, for which a flange width of only .65 in. would be required? From sample lengths welded with a spot elongated to .4 in. long and .18 in. wide, they had obtained extremely good results, each weld being quite satisfactory and, surprisingly enough, the weld strength showed an increase of approximately 22% over the standard weld. They thought that this would work well, but the welders did not agree. Why must they have a circular slug for spot welding? He did not think it was necessary.

Mr. Burton replied that it was not essential to maintain a circular slug, but it presented difficulties from the maintenance of the electrode form. On being informed that the gauges in question were 16 and 14, he said it ought to be possible to get a satisfactory weld on a flange width of .65 in. for the thickness used, using an elongated type.

Mr. Bradford replied that this had not been possible on actual aircraft parts.

Mr. W. Edwards, M.I.Prod.E. (*Senior Project Engineer, The de Havilland Aircraft Co. Ltd.*), asked whether the use of titanium was on the increase or the decrease in the United States. Was it being steadily discarded? If so, for what reason? It it were on the increase, what troubles, if any, had been experienced in operational use and what was the percentage cost added to the manufacture — excluding the cost of the material — through using titanium instead of other materials? Did Boeing still use a complete enclosed chamber for welding? If not, what system did they use to provide for complete gas coverage of the weld?

Mr. Bucey, in reply, said that titanium fitted into a certain part of the speed range; if they exceeded its capabilities they must use stainless steel or molybdenum and so on. It depended on the speed range in which they were interested. The Air Force had asked Boeing to make their improvements in large increments, and as a result of this requirement they felt that they would probably use less titanium than they had originally planned. The preliminary design of an aircraft a year ago planned to use 60% or 65% titanium, with the balance mainly steel, but that design today was almost exactly 50% steel and 50% titanium.

About a year ago they had encountered a problem of hydrogen embrittlement with the material, but

that had fairly well been overcome. One of the problems they had had until recently was that of thickness tolerance, but the suppliers had assured them that the tolerances could be cut in half, which had solved that difficulty.

They foresaw no problems in its use, but they were not yet using much in production, although they used some in missiles. As for welding, in their missile work they originally used complete enclosure in a plastic bag but they had trouble in getting rid of all contamination; they could not completely evacuate it. At the moment it was mainly bits and pieces, with a shield on top; if they were working in a tank, the system rotated so that it was upright as the tank rotated, or there was a fixed whole-length shield on the bottom. They had achieved very satisfactory results. If they wanted to do automatic welding they could, and it was difficult to do that in an enclosure.

Asked again what percentage it added to the costs per lb., Mr. Bucey replied: "I could not answer that. A lot".

The **Chairman** thanked the speakers, on behalf of the Conference, for the way in which they had stood up to some most difficult questions and, in particular, Mr. Bucey, who had been so frank. It had proved that Mr. Bucey was a real engineer, because he had admitted all the problems they had in America, which were exactly the same as in the U.K. When reading a Paper or answering questions there was a great temptation to make it sound as though one's Company had no problems at all, but Mr. Bucey had brought out the problems clearly, particularly when he had spoken about modifications, a subject about which they all knew so much. He had admitted freely that things did not work to schedule.

He asked the Conference to express its appreciation in the usual way.

The vote of thanks was carried with acclamation.

CLOSING THE CONFERENCE

Mr. D. L. Wiggins (*Chairman, Southampton Section*) said they heard many words of wisdom in the last couple of days, and it was merely his duty to wind up the Conference and to thank the speakers and the Chairmen. Each year the Committee attempted to improve on the preceding year's Conference. When they considered the standard which had been set by the speakers at the present Conference, they realised that their objective for next year would be extremely difficult to attain.

It was not his job to sum up the Conference, but he wanted to mention two points which he had appreciated — both made by Mr. Bucey. One was the interpretation of incentives as somewhat different from our own interpretation; namely, pride in the job being done. The second was the confirmation that Boeing and not the man in the shop ran their Company. This had encouraged him considerably.

On behalf of everyone, he thanked the speakers for their contribution to the Conference. Thanks were also due to the Chairmen for assembling the details of the Sessions into good sub-assemblies, with such perfection, as he was sure they would agree that the finally assembled Conference would need no modifications. He thanked the University and its staff — the thanks being to the Vice-Chancellor, Mr. D. G. James — for the facilities given for holding the Conference, and he thanked the Headquarters staff of The Institution of Production Engineers, particularly Miss Bremner, Miss Dancer and Miss Freeman. In declaring the Conference closed, he wished members a safe journey home and a Happy New Year.

The proceedings then terminated.

Output Pattern in Repetitive Tasks

with special reference to
Compensating Relaxation Allowances

by N. A. DUDLEY,
Ph.D.(Birmingham), B.Sc.(London), M.I.Prod.E.

PART II

output curves

During the First World War, investigations of output variations were promoted by the Health of Munition Workers Committee, which developed into the Industrial Fatigue Research Board already referred to by Dr. Smith. Concern had been expressed at the decrease of output that had resulted from the excessive working of overtime and, as a result of these studies, hours of work were reduced from 10 to eight, and recommendations were made for the introduction of rest pauses into the work shift to arrest the decline in the output rate which could normally be expected to occur, and thereby to increase productivity⁴⁷.

A critical examination of these investigations was made by Vernon (1921)⁴⁸ who recommends the study of "as large groups of workers as possible, to determine their output over a number of days, and to take averages. Irregularities of output, due to temporary variations in the state of fatigue of the workers, and in their reaction to psychical factors such as monotony and spurt are thereby eliminated, and a consistent and steady picture of their average output is obtained, upon which reliance can be placed".

Vernon reproduces Hourly Output Curves of such groups of workers to illustrate three typical features of these curves :

- (a) *Fall in output*, attributed to effect of fatigue. He observes: "Somewhat unexpectedly, it is quite the exception for hourly output curves to show a pure fatigue effect".
- (b) *Practice-efficiency*. "In some instances", says Vernon, "fatigue processes may never be sufficient to overpower practice efficiency, and the output may rise steadily throughout each spell of work."

(c) *End spurt*.

On this subject he says that the worker's "keenness may revive considerably in the last hour or so of the work spell, as he realises that a rest from work is at hand. He therefore puts on a spurt, which may completely mask a diminution in his time capacity for work, supposing it had been possible to test that capacity apart from psychical influences"

Vernon summarises thus: "The majority of hourly output curves do not show any one of the three typical features of fatigue, practice-efficiency and end-spurt to such a marked degree as in the examples recorded. Many of them appear to show a period of rising output, due to practice-efficiency, in the first part of both work spells, followed by a period of falling output due to fatigue in the last part of both spells". Vernon also records a "grave suspicion that part of the rise and fall observed, and sometimes even the whole of it, is due to loss of time in starting and stopping work".

Studies of output variations at short intervals during the day, on heavy and light processes, were promoted by the Industrial Fatigue Research Board which published several reports; by Vernon (1920)⁴⁹ on investigations in the Iron and Steel Industry, Elton (1920 and 1922)⁵⁰, Weston (1922)⁵¹ and Wyatt (1923)⁵² in Weaving, and May Smith (1922)⁵³ in the Laundry Trade. In 1927, reports on rest pauses by Vernon, Bedford and Wyatt were published⁵⁴, and in 1937 a report by Wyatt and Langdon on fatigue and boredom in repetitive work⁵⁵.

In 1943, May Smith⁵⁶ writes: "Owing to the shape when graphed, the curve is known as the saddle-back curve. It is characteristic of both manual and mental work, if there is no other change except the passing of the hours. It has been described as

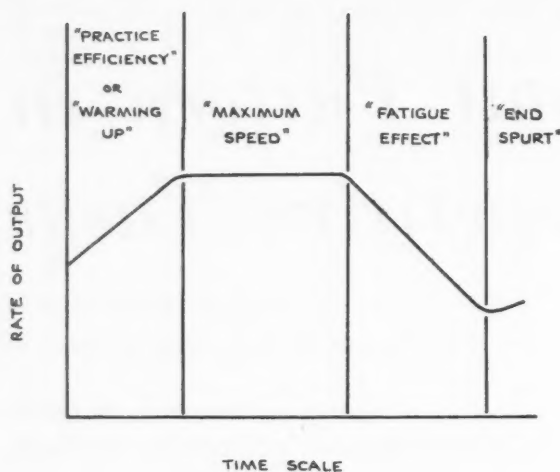


Fig. 1. Typical saddle-back output curve.

showing a sluggish start before the worker is warmed-up, a rise as he gets into his stride, a flagging, and a final falling-off in the last hour".

In 1947, Cohen⁵⁷ says: "Many output curves have been published. They show how the output of an operative or group of operatives varies in the course of the working day. All these published curves show a typical profile. The output starts at low level, then it increases gradually, after a few hours it goes down, and just before the lunch break it usually goes up again" (see Fig. 1).

Vernon⁵⁸ observed that: "Daily output variations show all the same features that are observed in hourly output variations. They are due to precisely the same causes, only these causes are operating over a longer interval of time, viz: the week instead of the day".

May Smith⁵⁹, whose references are all to the reports of the Industrial Fatigue Research Board, writes in 1943 that:

- "1. Output is nearly always low on Monday and at the end of the week.
2. The general shape of the curves is consistent with output being affected by two opposing factors:
 - (a) increased efficiency due to practice which causes a rise in output; and
 - (b) fatigue effects which accumulate during the course of the week and tend to cause a fall in output.
3. These opposing factors vary in strength according to the length of each working day, the kind of work and the experience of the worker. Output may reach its maximum on the second, third or fourth day of the working week".

Factors affecting output rate

Accepting that the "saddle-back curve" is, in general, typical of industrial operations, the factors which, it has been conjectured, give rise to these trends may be classified as:-

1. *Physiological*
 - (a) the effect of practice;
 - (b) the onset of fatigue;
 - (c) faulty posture.
2. *Psychological* (see, e.g. Elton Mayo's account of the Hawthorne Experiment⁶⁰).
 - (a) motivation;
 - (b) interest in work, or boredom;
 - (c) end-spurt;
 - (d) conscious restriction of output;
 - (e) attitude to supervision and to other workers;
 - (f) influence of domestic circumstances.
3. *Organisational* (the effects of which tend to accentuate or mask the effects of 1 and 2).
 - (a) hours of work;
 - (b) rest pauses;
 - (c) lost time;
 - (d) inadequate lighting, heating and ventilation;
 - (e) the degree of mechanisation;
 - (f) excessive noise and vibration;
 - (g) faulty machine design, badly functioning equipment and poor quality material.

Superimposed on these factors are the effects of variations in the same individual worker deriving from changes in mental attitude and physical condition, and the very considerable variations resulting from individual differences, both innate and acquired, within the working group.

time study limitation on output variation

Time study, in modern industry, cannot be regarded as an isolated and self-contained tool of management, but must be viewed as one of several complementary techniques which are collectively known as work study.

Work study has been defined as "The analytical study of all forms of productive work in every type of industrial activity, using, where appropriate, the techniques of method study, motion study and work measurement, with the object of improving productivity and working conditions" 61.

As noted above, time study is the technique of work measurement which is applicable to repetitive manual operations. At the outset, the time study observer checks that two basic conditions have been satisfied. The first is that the operation has been standardised. This standardisation of the layout of the work and method of working will normally have resulted from a systematic method or motion study. During the course of this prior method study, causes of fatigue will have been eliminated wherever possible, whether those causes be unsatisfactory working conditions — inadequate lighting, heating or ventilation, or excessive dirt, noise or vibration — or unnecessary or unnecessarily fatiguing elements of movement or unnecessarily fatiguing posture.

The second condition is that the operation is being performed in the approved manner by a trained and experienced operator. Careful selection of the worker ensures that the work is within his physical and mental capacity and yet makes reasonable demands on him, while training and experience still further reduce the likelihood of abnormal fatigue. As Vernon 62 states in his "law of maximum production with minimum effort": "Experienced industrial workers unconsciously adopt habits of work which tend to the production of a maximum output with a minimum effort".

The establishment of these conditions before a time study should be undertaken, together with the effects of current practice and legislation relating to hours of work and rest pauses, and the trends towards mechanisation of industrial processes, severely limit the range of output variations which can be attributed to the involuntary effect of practice or the onset of fatigue. Certainly, if "measures of neuromuscular changes are really most valuable when we are approaching the limits of performance", they have no field of application here.

time study rating and C.R. allowances

Although this thesis is concerned primarily with the investigation of output variations as a contribution to the theory of C.R. allowances, the fact that rating is also concerned with compensating for certain output variations, namely, voluntary changes in working pace, necessitates an examination of the relationship of these two assessments. As stated

above, the distinction between rating and C.R. is quite clear to time study practitioners; research, however, indicates that there is some interdependence and interaction between the two.

The University of Birmingham Report 63 on the investigation of time study practice states: "Examination of the results shows that there is a small but significant effect on the normal time due to the C.R. allowances. On the average, an increase of 1% in the C.R. allowance was associated with a decrease of 0.12% in the normal time, the scatter among the allowed times will be greater than the scatter among the normal times".

In other words, when the time study observer uses a high C.R. allowance for a particular element or operation, he tends to off-set this, to some extent, by over-rating the operator's working pace and thus under-estimating the normal time, and *vice versa*.

The Society for Advancement of Management, U.S.A., Research Report on "Rating of Time Studies" 6 states: "One of the most interesting and important discoveries of the Rating Project has been that rating is done in conjunction with certain general allowances, that are to be applied later to the normal time. The size of these allowances has an important effect upon the way the rating scale is actually employed. For example: if allowances, which include personal, fatigue and catch-all general delay allowances are comparatively high, the rating scale is employed in such a way that ratings of instantaneous performance are comparatively low or tight. On the other hand, if allowances are low or perhaps inadequate, the same rating scale is employed in such a manner that instantaneous performance is rated comparatively high or loosely".

Quite apart from this, it is clear that although rating is merely an assessment of actual working pace relative to a normal pace, the establishment of the normal pace involves consideration of the effort demanded by the nature of the operation.

Normal pace is achieved when a worker is producing 60 units of work per hour. It has been agreed that this pace is demonstrated by "a man of average stature walking at three miles per hour, unloaded, on level ground, and under normal atmospheric conditions". One observes, at this pace, "free, balanced and natural movements" which are "the movements of a man doing his work methodically, but lack that crispness associated with movements carried out with a clear and definite purpose" 64.

Under these conditions walking at four miles per hour is equivalent to a pace of 80 work units per hour. "Here again the movements are free, balanced and natural, but in addition convey the impression that they are being performed with a definite objective. Although clearly purposeful, they do not convey any sense of urgency and strain. These are the movements of a trained man working conscientiously at a steady performance, which can be maintained without any undue fatigue" 64.

Thus, although "an allowance of time for the recovery from fatigue caused by the nature of the effort" is included in the work unit, which occupies one minute at a normal pace, a pace of one-third above normal "can be maintained without any undue fatigue".

In order to satisfy this condition, a man of average stature walking at four miles per hour under the above stated conditions, but carrying a load, would be rated higher than 80, and consequently the normal pace for this operation would be less than three miles per hour. Hence, in the process of rating, allowances of time are made for differences in effort demanded by operations; that is, allowances are made for the fact that some jobs are more fatiguing than others. C.R. allowances, also graded according to effort, are additional to these.

As an operation proceeds, it seems reasonable to suppose that because of the operator's diminishing capacity for work resulting from the onset of fatigue, an increasing effort needs to be applied if the rate of working is to remain constant. In practice, one observes a varying amount of effort and a varying rate of working. Ignoring the effect of fatigue, it would appear from the manner in which the normal time is calculated, viz :

$$\text{Normal Time} = \frac{\text{Actual Time} \times \text{Rating Factor}}{\text{Normal Rating}}$$

that the product of the actual time taken to perform an element of an operation and the rating factor is a constant. It follows, therefore, that variations in time taken will, in theory, be compensated for in the process of rating.

However, whereas an operator working at a normal pace will take a certain normal time to perform an operation, the same operator, when fatigued, will have to exert a greater effort to achieve this time.

Accordingly, it would seem that the time study observer is faced with two alternatives; either to study an operator who is not only trained and

experienced but also refreshed, and then to make some allowance for the effect of fatigue, or to rate in such a manner that this fatigue is taken into account during the study.

On the basis of "the typical saddle-back output curve", it might be argued that, insofar as this represents variations in working pace, the timing and rating of samples of operation elements selected from the various phases of the curve would compensate not only for the voluntary variations in pace, but also for the gradual reduction in pace described as "an automatic adjustment to fatigue", as well as for the upward trends due to "practice efficiency" and "end spurt".

To test this hypothesis, examination was made of a number of continuous time studies of repetitive manual operations, extending throughout the working day. Rates of output and ratings made by experienced time study observers during one of these studies are recorded in Fig. 2.

Comparison of these curves suggested that either :

- (a) the observers modified their concept of normal as the operators became progressively more fatigued; or that
- (b) the observers distinguished between voluntary changes in pace and changes in pace due to fatigue, rating only the former, and hence allowing the normal times to increase; or that
- (c) the operators maintained a consistent pace, other factors accounting for the shape of the output curve.

Subsequent examination showed that there was no significant trend in the normal times for the operations, calculated from rating assessments and independently recorded operation cycle times.

It was therefore clear that :

1. the observers did not modify their concept of normal as the operators became progressively more fatigued;

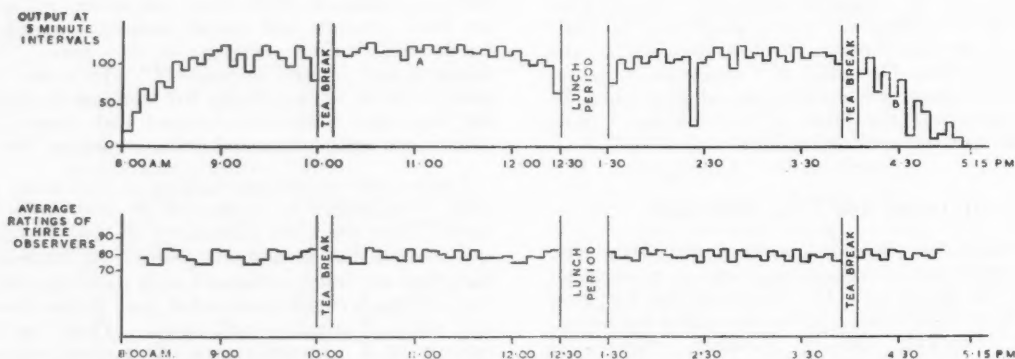


Fig. 2. Rate of output and performance ratings. Operation : Thread roll bulb holder.

2. the observers did not distinguish between voluntary changes in pace and changes in pace due to fatigue, rating only the former. On the contrary, it was clearly established that
3. the operators maintained a consistent pace and that, therefore, other factors accounted for the shape of the output curve.

preliminary hypotheses

The effects of fatigue may be evaluated by examination of the results of:

- (i) carefully controlled physiological and psychological tests and experiments;
- (ii) subjective assessments; and
- (iii) performance records.

In the context of time study, in which operator effort has been reduced to a minimum by method and motion study, physiological and psychological experiments, as developed, have, as yet, little application, while, even with trained observers, subjective assessments of fatigue are of doubtful value.

The most profitable line of approach in the study of C.R. requirements, therefore, seemed to be the analysis of performance records, in particular of the output pattern.

Although the range of performance is strictly limited in time study by the insistence upon a trained and experienced operator and a standardised method of working, it was recognised that it would be necessary to ensure that the records studied did not represent abnormal performances and that reasonably high working paces were maintained. It would also be necessary to make checks to ensure that the operators did not suffer more than "normal healthy fatigue"; in other words, that there was no cumulative fatigue effect over successive working days.

Even under these conditions, it might be argued that variations in operator performance, which may be attributed to diminishing capacity for work, may not be effects of "true fatigue", while other fatigue effects may not be revealed in the worker's performance. The only effect, however, with which the time study observer, as such, is concerned, is the extent to which diminishing capacity for work — due to "true fatigue" or any other cause — actually slows down the rate of output.

It has been shown that there is some evidence that:

- (a) in establishing his concept of normal pace for an operation, the time study observer is influenced by the effort demanded by the nature of the work and thus, to some extent, makes an allowance for the degree of fatigue in the process of rating; and that
- (b) variations in working pace, not involving major changes in method, are recognised as such by the time study observer and allowed for in the process of rating.

Thus, it seemed that the determination of fatigue effects which are of direct interest to the time study engineer in practice resolved itself into a study of lost time and of non-standard elements, occurring at different stages throughout the working period.

Nevertheless, it has been shown that a considerable body of literature supports the view that trends in rates of output during the working period are to be interpreted in terms of "practice efficiency" or "warming up" and "onset of fatigue".

Two opposing hypotheses, therefore, were postulated to explain the phenomena of the saddle-back output curve insofar as it relates to trained and experienced workers engaged on repetitive manual operations:

1. During the work shift, the operator increases his pace to a maximum which he maintains until physical or mental "fatigue" results in a gradual reduction in pace from work cycle to work cycle, towards the end of the working period.
2. During the work shift, the operator maintains a consistent working pace, but interruptions to the sequence of work cycles, due to personal and operational delays and ancillary work, result in trends in the rate of output at different stages in the working period.

Research project nature of the problem

The range of manual tasks in industry is extremely wide, and the conditions of work differ greatly from one industry to another. The factors affecting the performance of the worker are likewise extremely varied, and are also interdependent from the physiological and psychological point of view. The establishment on a scientific basis of comprehensive and detailed schedules of C.R. allowances covering all conditions and types of work — should this be deemed to be necessary or desirable — would therefore be a major task.

Before engaging upon a major research project of this nature, which would involve the services of a large team of specialist investigators, it was considered desirable to dimension the problem from a practical engineering production point of view, and to determine whether such a project was in fact necessary and, if so, the form it should take.

It may be observed that C.R. allowances, as at present awarded in time study practice, have the merit that they are, in general, acceptable to both management and workers.

Furthermore, time study is essentially a sampling technique and, in arriving at a standard time for a repetitive operation on the basis of a relatively small sample of work cycles, it is not unreasonable to add "allowances" related in some way to the nature of the task. It is clearly desirable, however, to provide a scientific basis for such a "factor of safety", as far as study techniques and the development of general principles will allow.

As stated in the S.A.M. Rating Survey Report 65 : "The concept of short-term performance is relatively unimportant, except as a means to an end. Whether a person works rapidly and takes a great deal of rest time, or whether he works at a more moderate pace and takes no rest time, may have little bearing on how much he should produce in an eight-hour day — the fair day's work".

For economic reasons, however, the pattern of activity over the working shift is not normally determined, although different types of work might be expected to show different output patterns. Thus, although allowances are made for such variations, knowledge of their causes is extremely limited.

Before attempting to develop a theoretical relationship between the pattern of activities for a given task over the working shift, and the C.R. or other allowances which should be made, it was considered necessary to establish the nature and causes of changes in this pattern, and to dimension the effects on output.

definition of objectives

Having in mind the wider issues involved in the development and application of C.R. theory to time study practice, outlined above, the primary objectives of this present research project were :

- to test the alternative hypotheses set out above by a detailed study and analysis of the pattern of activities of manual workers engaged upon repetitive tasks;
- to provide a more satisfactory explanation accounting for the output trends indicated by the "typical saddle-back" curve than those previously advanced; and
- to determine more exactly the lines along which future research on compensating relaxation theory and its validation should be conducted.

Research procedure

selection of operations

The operations, from which the data for this research were obtained, are all actual industrial tasks

performed under current working conditions. In order, however, to establish certain controls for study purposes, the operations were selected with the following limitations :

- that they must be representative of the main classes of manual work, where variations in the time taken to perform an operation are very largely determined by the physical effort or dexterity of the worker, as, for example, in manual work with or without the use of tools, and work involving machines guided or driven by hand or foot;
- that they must be free from external "flow-line" control;
- that the method of performing the operation has been standardised;
- that they are performed by trained and experienced operators;
- that they are repeated continuously throughout the period which is customarily worked;
- that the physical working conditions (temperature, humidity, ventilation, lighting, noise, vibration and dirt) are not abnormal for the type of work involved.

classification of operations

Industrial manual operations were classified, as shown below, according to the sex and posture of the worker, the muscular effort involved, and the degree of visual attention required in performing the operation.

This broad classification was used to ensure that the operations selected as samples for study were representative of the wide range of manual tasks.

index of operations studied

The operations selected for detailed analysis are tabulated and classified below. The list excludes check studies noted in the results and made for purpose of comparison.

Muscular Effort	Posture	Sex	Closeness of attention		No.
			High Degree (a)	Low Degree (b)	
Light	Seated	M	X		I
		F	XXX	X	II
	Standing	M	XX		III
		F	X	XX	IV
Medium	Seated	M	X		V
		F	XX		VI
	Standing	M	X	X	VII
		F	X	X	VIII
Heavy	Peripatetic	M		X	IX
	Standing	M		XX	X

The classification of the operations selected for analysis is indicated thus : "X" in the above Table.

Operation Number	Operation	Classification	
		Sex of Operator	No.
1	Jewellers' Bench: Setting Marcasites	M	Ia
2	Sewing Machine: Stitching Rayon (1)	F	IIa
3	Sewing Machine: Stitching Rayon (2)	F	IIa
4	Hand Press: Pierce "Burner Guard"	F	IIa
5	Foundry Bench: Core Making. "Burner"	F	IIb
6	Foundry Bench: Core Making. "Rails"	F	IVb
7	Polishing Mop: Polish "Burner Guard"	M	IIIa
8	Polishing Machine: Polish "Gas- lighter Cap"	M	IIIa
9	Sorting Operation: Sub-racking Sheets	F	IVa
10	Laundry Press: Press Handkerchief	F	IVb
11	Factory Bench: Assemble "Torch Switches"	M	Va
12	Hand Press: Reform "Top Cap"	F	VIa
13	Hand Press: "Tip Lamp Body"	F	VIa
14	Drilling Machine: Drill "Cylinder Head"	M	VIIa
15	"Bulge End of Tube"	M	VIIb
16	Iron Foundry: Mould Castings ...	M	Xb
17	Hand Press: "Clip Top Cap" ...	F	VIIIa
18	Laundry Press: "Press White Coats"	F	VIIIb
19	Draw Bench: Tube Drawing ...	M	IXb
20	"Hot Swaging" Tubes	M	Xb

techniques of recording data

Recording techniques employed in this research included:

1. *Production Studies*, in which the nature and duration of operation elements and non-productive time were noted by direct observation and recorded throughout the work period in chronological order.
2. *Automatic Time Recorders*, which enabled the distribution of productive and non-productive time to be recorded over several successive days.
3. *Memomotion Studies*, involving the use of a specially geared ciné camera taking shots at one-second intervals, which enabled the performance of several operators to be recorded simultaneously throughout the work period.
4. *Micromotion Studies*, during which the elements of worker movement involved in operations were filmed at intervals throughout the work period, and analysed for comparison.
5. *Activity Ratio Studies*, involving snap readings of activities and delays throughout the work periods, and from which the average distribution of productive and non-productive time for groups of workers engaged on identical operations was determined.

In addition, the several firms concerned made available, for examination, records of individual operators including details of experience, of output and of hours worked.

study safeguards

In order to ensure that performances during the periods studied did not represent abnormal behaviour on the part of the operators involved, several precautions were taken:

1. External Checks

- (a) Studies were made only in companies having Work Study Officers, responsible for establishing the work methods employed.
- (b) In all cases, the operators concerned had worked satisfactorily at their tasks over long periods of time.
- (c) Operators were studied while working during their normal work periods, and taking their customary breaks.
- (d) Production records for the period of each study were compared with the figures for corresponding periods before and after each study for the operators concerned.
- (e) Different operators were studied on the same and similar tasks.

2. Internal Check

Frequency diagrams of element and cycle times were examined as indications of the general level of operator performance, and of changes in the level at different periods throughout the work shift.

techniques of analysis

The following techniques of analysis have been employed in the study of the recorded data:

1. Mathematical Analysis. Comparison of:

- (a) output rates of individual operators on successive days;
- (b) output rates of different operators on the same day;
- (c) the percentage distribution of productive and non-productive time for morning and afternoon shifts;
- (d) elemental motion times at intervals throughout the work period.

2. Statistical Analysis

- (a) The computation, for successive samples of operation element and cycle time through the study, of the sample mean, range and variance, and of appropriate control limits.
- (b) regression analysis of element and cycle times.
- (c) the analysis of frequency diagrams of element cycle times recorded during different periods of the work shift.

3. Graphical Analysis. The construction of:

- (a) graphs of output rates and the periodic distribution of productive and non-productive time;
- (b) frequency diagrams of operation element and cycle times;
- (c) graphs presenting the statistical analysis detailed in paragraph 2(a) above.

To be continued

(References overleaf)

NOTICE OF COUNCIL ELECTIONS 1958-9

NOMINATIONS

- (a) In accordance with Article 43, nominations are invited to fill nine vacancies for elected members to serve on Council for 1958-1959 (i.e. eight Members and one Associate Member).
- (b) Before candidates are nominated for election, their consent must be obtained.
- (c) Candidates for election must be nominated in writing by three *Corporate Members of the Institution.
- (d) In addition to nominations as in (c) each Section Committee may nominate one candidate.
- (e) Nominations must reach the Secretary at 10 Chesterfield Street, London, W.1, not later than Monday, 28th April, 1958.
- (f) The members listed below are due to retire and are *not* eligible for re-election as elected members until at least one year has elapsed.

Members :

H. W. Bowen, O.B.E.
H. Burke
F. J. Everest
A. Griffiths, O.B.E.

Sir Stanley Harley
H. W. Hodson
A. L. Stuchbery
Dr. C. Timms

Associate Member :

R. S. Clark

By Order of the Council,
W. F. S. WOODFORD,
Secretary.

APRIL, 1958

*Corporate Members are: Honorary Members, Members, Associate Members.

"Output Pattern in Repetitive Tasks"

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Quarterly Newsletter to the Institution

Brief review of PERA activities in 1957

Important developments which took place at PERA during 1957 included the occupation of the new workshops and laboratories, the creation of an Education and Training Department, and the introduction of a form of Associate Membership open to all technical colleges and universities in Britain and the Commonwealth. Membership increased substantially, more than 120 large and small firms in a wide range of industries joining the Association during the year.

General investigations were carried out into impact (cold) extrusion of steel, deep drawing, automation, vibration, friction and lubrication, machine tools, de-burring, finish blanking, cutting fluids, tool materials, etc. About 230 special problems and development projects were also undertaken for individual member firms. These included the performance of ceramic tools, cold extrusion of aluminium and steel components, machining of stainless steels, Nimonic alloys and titanium, finish blanking of high tensile steels, vibration of machine tools and other production equipment, grinding of cutting tools, etc.

Research

Brief details of some of the work carried out in 1957 are given below:

Cold extrusion

Considerable progress has been made in investigations into the impact (cold) extrusion of steel. Experiments have been started on the cold extrusion of large components using the recently installed

1,000-ton press. Current research includes investigations into the properties of steels for impact extrusion, variations in extrusion pressure with percentage reduction in area, and the conditions of lubrication required for backward extrusion.

Finish blanking

Research has been continued into the finish blanking technique, which produces pressings with smooth edges. This technique frequently eliminates expensive shaving or machining operations in the production of pressings and is being applied in a growing number of industries in the manufacture of cars, electrical goods, etc. In one firm, a saving of £3,000 was effected in the production of the first component to which finish blanking was applied. Still wider application of the technique is expected when work on other materials is completed.

Deep drawing

Investigations were continued to determine the relative efficiency of various lubricants when deep drawing a number of materials. The results of this investigation are expected to provide a reliable basis for the comparison of a wide range of lubricants which are at present selected largely by trial and error. Continuation of work on another investigation has confirmed that depth of draw can be increased under conditions differing markedly from normal practice.

Metal cutting

Research was initiated to compare the performance of three types of high speed steel when machining

A member firm's engineer, seconded to PERA for a course of training in vibration research, carrying out tests on an experimental damped boring bar.



alloy steel. The opportunity is being taken during this research to investigate the relationship between tool wear and workpiece diameter. Work was also begun on an investigation to compare the performance of various cutting fluids and the effects of different methods of application when machining high tensile nickel-chrome steel with carbide tools.

Ceramic tools

Practical work was completed in an investigation of the performance of a range of makes of ceramic tools when turning alloy steel. Comparison tests were also carried out on cemented carbide tools. Performance was assessed on the basis of tool wear in roughing operations and on workpiece surface finish and wear in finishing operations. Economic aspects of the use of ceramic tools were explored by carrying out tests in which the effects of various feed and speed combinations giving constant rates of metal removal were determined.

Machine tools

An investigation into the accuracy and performance of several makes of cylindrical grinding machine has been completed, and substantial progress has been made in an investigation into various aspects of machine tool slideway lubrication and slideways. A report is being prepared on the influence of scraped surfaces, lubricant viscosity, load per unit area, and sliding speed on the transition from boundary to hydrodynamic lubrication. Practical tests are also being carried out to determine the friction properties of various lubricants and machine tool slideway materials.

Research into various aspects of machine tool vibration has continued during the year, and progress has been made in the development of experimental vibration absorbers. By using these absorbers, excellent surface finishes can be produced in some machining operations under conditions which otherwise result in severe chatter, rough surfaces and, in extreme cases, tool breakage.

Information services

Heavy demands continued to be made on all information services in 1957. Nearly 2,000 technical enquiries were answered, and approximately 700 requests for information on a wide variety of subjects were also dealt with. Examples of gains in productivity in firms applying PERA's recommendations include a 300% rise in turnover in the manufacture of metal furniture. The output of a firm making handling plant was increased by more than 30%, and the introduction of better production methods saved another company £20,000 per year. Typical of layout problems handled was that of a firm which had to concentrate its production into a building roughly half the size of the existing works to obtain vitally needed storage space.

To assist members in making the most effective use of PERA research results and recommendations,

approximately 800 visits were made by engineers to factories in all parts of Britain.

Films were made by the PERA film unit on drilling, and methods improvement.

Education and training

At the request of members, the series of courses on improved production techniques, first held in 1956, was repeated in 1957. A new series of courses on metal cutting began in June, and was attended by hundreds of foremen, shop managers, superintendents, methods engineers, etc.

Short refresher courses were also held for workshop personnel such as foremen, tool grinders, etc., on machine tool maintenance, press setting, tool and cutter grinding, etc. Over 20 young engineers took the six-month student course which includes practical experience with PERA research teams, lectures on various aspects of production from research engineers, a series of organised discussions, and visits to factories specially selected to demonstrate the application of up-to-date production techniques in various industries.

The Mobile Unit visited approximately 140 factories in Scotland and the North of England and nearly 11,000 key personnel at all levels in industry saw demonstrations, illustrated talks, and films on improved production techniques developed by PERA.

Enquiries regarding the activities of PERA should be addressed to:

THE INFORMATION MANAGER,
"STAVELEY LODGE",
MELTON MOWBRAY,
LEICESTERSHIRE.

RESEARCH PUBLICATIONS

The Institution is advised by PERA that Dr. G. Schlesinger's book on "Accuracy in Machine Tools: How to Measure and Maintain It" is now out of print and cannot, therefore, be supplied. The following I.Prod.E. publications are, however, still obtainable from PERA at "Staveley Lodge", Melton Mowbray, Leicestershire.

"Practical Drilling Tests" by D. F. Galloway and I. S. Morton. Price 21s.

"Machine Tool Research and Development" by D. F. Galloway. Price 10s. 6d.

EXTRACTS FROM

REGION AND SECTION REPORTS

Presented to Council on 30th January, 1958

EAST AND WEST RIDINGS REGION

Halifax and Huddersfield

A very enjoyable evening was spent by members and their friends at the Dinner and Dance held in Halifax in October. Unfortunately, at the last minute Mr. E. W. Hancock, O.B.E., was taken ill and was unable to attend, but Mr. J. E. Hill replied to the toast "The Institution of Production Engineers" in Mr. Hancock's absence.

After the last Committee meeting, which was held in the new Percival Whiteley Technical College, Halifax, members of the Committee were conducted round the building by Mr. K. D. Walker, Head of the Engineering Department, and member of the Halifax and Huddersfield Committee.

Halifax and Huddersfield Graduate

The first two lectures of the session were attended by the largest audiences for many years, and a visit to Hepworth & Grandage Limited was most successful.

After discussing the qualifications for membership of the Institution, this Committee feels that all grades above Student should require the same academic qualifications. It is felt that the Institution's prestige can only be raised among engineers by a strict insistence on academic qualifications.

Leeds

It is hoped that as many members as possible will support the lectures during the next part of the session.

Mr. Wilson, a member of the Committee, attended the Materials Handling Convention at Leamington Spa in October, 1957. He gave a full report to the Committee, and an endeavour is being made to form a local group.

The Annual Dinner of the Section will be held on 12th April, 1958, at the Griffin Hotel, Leeds.

Leeds Graduate

The Leeds Graduate Section have held three works visits; the first was to the G.P.O., Leeds; the second visit was to the Melbourne Brewery, Leeds; and the latest was to the National Coal Board, No. 7 Headquarters, Wakefield.

The increasing support from members displayed by attendance on these visits is very gratifying, but the Committee are still anxious to increase attendances at meetings.

Sheffield

During the last three years, the Committee has spent much time debating the "Broadening the Base" policy, particularly the proposed changes to the examination structure, and looks forward with interest to the publication and implementation of the revised examinations syllabus.

Representatives on the Research and Standards Committee recently presented reports on the activities and future commitments of their respective committees. These reports, which are most comprehensive, provide material for stimulating discussions and are greatly appreciated by the Committee.

Sheffield Graduate

The programme of practical lectures still continues to be very successful. Their popularity is spreading, as can be seen from the fact that no less than 15 'new' firms have been represented at the last three lectures. From a prestige and membership point of view, this fact must be of great value to the Institution.

As a further service and in order to publicise the Institution's work, with the co-operation of the Hazleton Memorial Library, duplicated bibliographies on the lecture subject are being distributed at each meeting.

The next National Graduate Representatives Conference is to be held in Sheffield in the Spring of 1959. Plans are being made to make this an interesting and successful meeting.

The Sheffield Graduate Committee is now stronger than ever before, having 10 regular members. The outlook for the future is just as bright as a number of other young members are showing a keen interest in our activities.

EASTERN REGION

Ipswich and Colchester

The first social function proved to be most successful, under the Chairmanship of Mr. L. A. Childs, with Mr. J. E. Hill, Vice-President of the Institution, as Guest of Honour. There appears to be no doubt that a Social will now become a regular part of the Section activities.

Three very interesting lecture meetings have been held this session, the first being at Colchester during October. This was a combined meeting with the Colchester Engineering Society, when a Paper on the "Development of Transfer Equipment" was read by Mr. A. J. Sephton.

The Chairman's Address was given at the November meeting, when Mr. L. A. Childs spoke on "Developments in Machine Tool Drives".

During early December, this Section received a visit from Mr. F. W. Cooper, the Institution's Education and Technical Officer. After college visits during the day, Mr. Cooper joined in the many discussions at the Section Committee meeting and the visit enabled Committee members to discuss various matters, including the structure of the membership examinations of the Institution.

Norwich

The first lecture meeting for the 1957-1958 session was held in September, at the Norwich Technical College, when Mr. W. W. Braidwood gave a Paper entitled "S.G. Iron — A Versatile Metal". This was a joint meeting with the Institute of British Foundrymen and the Norwich Engineering Society: there was a very good attendance and the lecture was most interesting.

A Paper on "The Use of Time Lapse Photography in Work Study" with films and slides, was presented by Mr. A. G. Northcott at the Assembly House, Norwich, in October. A very good discussion followed the lecture and the proceedings had to be drawn to a close owing to time limitations.

MIDLANDS REGION

Regional Report

The Regional Committee has met twice this quarter and plans are well advanced to co-ordinate the efforts of the respective Sections within the Region.

The first Regional meeting this session will be noted as being one of the most successful and interesting meetings held in the Midlands. In December, at Wolverhampton, Dr. J. E. Littlechild gave his Paper "Production Problems Associated with Industrial Atomic Energy". The pattern of production and application that has been building up in this new industry was brought vividly into focus.

The second Regional meeting will take place on 24th March, 1958, at Coventry, when Mr. H. Eckersley, M.I.Prod.E., will present a report on his experiment into the application of ceramics as metal cutting tools.

The Chairman reported a number of notable acceptances of invitations to attend the Regional Dinner on 18th April, 1958, in Birmingham, indicating the growing importance of this function within the Region.

The Regional Conference will be held in May, 1958, with a theme: "Machine Tools of the Future". The venue will be The Auditorium, Cincinnati Milling Machines Ltd., Birmingham.

In the field of education plans to establish a short scholarship for Midland Region Graduates has been under discussion with a view to furthering the link with the Department of Engineering Production, University of Birmingham.

Mr. H. J. W. Smith has resigned from the Committee upon taking up an appointment at Liverpool. He takes with him good wishes of the Committee.

Birmingham

The Birmingham Section's activities this quarter have provided members with a variety of subjects for the lectures.

"The Technique of Tube Making", by Mr. L. C. Hackett, of Accles & Pollock Ltd., in October, was a thorough and well-illustrated talk on the various methods of making tubes in various metals. The historical development was briefly surveyed and the advantages and disadvantages of the different methods explained.

As guests of Shell-Mex & B.P. Ltd., some 120 members were entertained at the Midland Hotel in November, and listened to a talk by Dr. C. B. Davies on "Industrial Research in the Oil Industry". The lecture showed that an enormous amount of research of immediate practical value to production engineers is undertaken by the major oil companies, for example, in the field of lubrication.

In November, a small group of members listened to Mr. T. B. Worth's Paper "Some Aspects of Technical Education in the U.S.A.". Mr. Worth had spent many months in America examining the methods used for higher technical education.

A successful Christmas Ball was held at the Botanical Gardens in December, when a large and very happy crowd of members, their wives and friends enjoyed a festive occasion which well marked the first of our social events this season.

A News Sheet is being issued to members and member firms this session to help keep them better informed of matters of production engineering interest in the Midlands, and to give them some insight into the future events on the programme. This is being issued three times a year and the second number is already in the hands of the members.

The announcement of a trip to the Brussels Fair at a special rate for Birmingham Section members and their wives has already appeared in the Journal. One plane load has already been allocated and a further aircraft is being arranged. This trip will enable members to have a few days at the Fair and around Brussels for a very moderate inclusive fee, and to fly from and return to Elmdon.

Birmingham Graduate

The Third National Student and Graduate Convention was held in November at the University of Birmingham.

An address of welcome was given by Dr. N. A. Dudley, B.Sc., Ph.D., M.I.Prod.E. The programme consisted of

three lectures dealing with Manufacturing, Organisation and Methods, and Accounting, each by a prominent speaker in his own field.

Each Paper was followed by its own discussion period, with a final summing up by Mr. F. W. Cooper, B.Sc., M.I.Mech.E., M.I.Prod.E., Education and Technical Officer to the Institution.

On the following day the Graduate Representatives Conference was held, and produced a lively discussion.

Two lectures have been given this session. The first was entitled "Developments and Applications in the Manufacture of Glass Fibre", presented by Mr. A. Pimblett, B.Sc.; and the second, "Value Analysis", by Mr. J. Rawicz Szczepko, Grad.I.Prod.E.; the latter being one of our own Graduates, who after presenting a 10-minute Paper at the last Graduate Papers Evening and winning the Chairman's Prize, was then invited to give a full Paper.

Continuing the publicising of the work of the Institution in local towns, a Film Show was held at the Foley College, Stourbridge, and was well supported by the College and local industry.

Coventry

Attendances at lectures continue to give cause for satisfaction, and it was perhaps appropriate that Mr. J. Harris, who had recently returned from a visit to Russian factories, was in the Chair for the October lecture entitled "Russian Machine Tool Industry (Some Impressions of a Recent Study Made in Russia)" and presented by Messrs. Norman Stubbs, M.B.E., and Peter Trippe.

Over 130 members and visitors were present at the November lecture, entitled "Modern Gear Hobbing Practice", given by Mr. Heydrich, of the German Pfauter Company. This was followed by a colour film.

In connection with the newly established Materials Handling Group, plans are in hand for formulating a Working Party from the Section and Mr. Evans, Grad.I.Prod.E., has been elected Section Representative. Any member interested in this Working Party may obtain particulars from the secretaries of either the Senior or Graduate Section.

The Annual Dinner and Dance was once again a most successful and enjoyable event, being attended by over 200 members, friends and their ladies. The function was honoured by the presence of The Lord Mayor of Coventry, Alderman Mrs. P. M. Hyde, with her daughter The Lady Mayoress, Lord Halsbury, President of the Institution, and a number of local industrialists.

Coventry Graduate

It has been the custom, of recent years, for an invitation to be extended to a prominent industrialist of the City of Coventry to talk to the Graduates on a subject entirely of his own choice. It was fitting that for this session Mr. E. W. Hancock, O.B.E., was asked to speak on "My Experiences as President of the Institution", and both Senior members and Graduates who attended the meeting in November will long remember the occasion.

Mr. Hancock gave an account of his early association with the Institution, in the days when meetings were held in London on Saturday afternoons, and quoted many extracts from Papers which he had given to various Sections throughout the country. In a vote of thanks to Mr. E. W. Hancock given by the Secretary, Mr. B. Brewster, an extract was taken from one of the first Papers Mr. Hancock had read to the Institution.

Some 35 Graduates were present when Mr. J. Tye gave a lecture on "Dynamic Balancing — A Growing Production Problem", which was illustrated by slides. A week prior to the meeting Mr. Tye was at the Hanover Machine Tool Exhibition and he was thus able to give an up-to-date account of how Continental engineers were facing up to the problem of Dynamic Balancing.

In December, Mr. A. E. Adams, Chief Engineer, Messrs. Scrivener Ltd., gave a very interesting talk to the Section on "Centreless Grinding" and some 80 slides were shown to this end. This talk will be amplified to some extent on 18th January, when a works visit to Messrs. Scrivener Ltd. will be held.

With regard to works visits, the Section are indebted to Messrs. Jones & Shipman Ltd., Leicester, who very kindly received a small party of Graduates to the Works in November.

Shrewsbury

Three well-attended and interesting lectures have been held. Another Annual Dinner and Dance has proved successful, both financially and socially. The Section was grateful to have the President and the Secretary of the Institution present to contribute to the success of the evening.

The Committee have considered current industrial developments in the Shrewsbury area and foresee that they may lead to increasing strength of the Section membership.

Wolverhampton

Normal lecture meetings were held in October and November, but in December the Wolverhampton Section was the privileged host for a Midland Region Meeting, when a Paper entitled "Production Problems Associated with Industrial Atomic Energy" was presented by Dr. J. E. Littlechild, of the United Kingdom Atomic Research Authority. This was undoubtedly an outstanding Paper and was very well attended.

Possibly the most notable and salient features of this meeting were in the diversity and essentially engineering characteristics of the lecture. When a physicist talks on atomic energy, one is normally prepared for a "technical fly past", but on this occasion the lecturer provided engineers with the kind of material and facts they could appreciate and this was evidenced by a lengthy and lively discussion.

In November, the principal social event of the year took place when a Dinner-Dance was held at the Mount Hotel, Tettenhall. Yet again, this was a most enjoyable occasion.

Wolverhampton Graduate

The Annual Dinner-Dance was held in November, when over 100 members and friends attended and thoroughly enjoyed themselves.

Discussions have taken place in the Committee as to whether to hold lectures outside Wolverhampton, but it was found that the majority of the audiences were travelling from Wolverhampton to attend the lectures.

Worcester

The first lecture of the session entitled "Accurate Measurement of Engineering Production" by Mr. J. Loxham, F.R.S.A., M.I.Mech.E., M.I.Prod.E., was given at Redditch and the good attendance fully justified the excellence of the lecture. A further lecture will be held at Redditch on 27th February.

The Section was very sorry that Mr. J. A. Grainger could not give his lecture on "High Speed Press Work" at Worcester in October due to illness. However, several very interesting films were shown instead, and thanks are due to Mr. A. C. Turner, the Regional Honorary Secretary, for helping to obtain films at short notice.

A very interesting lecture on "Mechanical Handling" was given by Mr. Bridge, in the absence of Mr. O. J. B. Orwin, and was followed by a film showing examples of how mechanical handling has speeded up production in many industries. A lively discussion ensued from the good attendance of members and visitors.

During the remainder of the session two lectures, a film show and a works visit have been arranged.

Newcastle upon Tyne

Committee meetings held during the quarter have been well attended.

The "Atom 1958" Exhibition of the U.K.A.E.A., is being sponsored in Newcastle early in 1958, and Mr. H. B. Topham is representing the Section on the Organising Committee.

Lecture meetings have also been well attended and the Papers have been presented by local authors. The subject for the October meeting was "Production of Astronomical Telescopes" by Mr. G. M. Sisson, O.B.E. M.A.; and for

the November meeting, Mr. J. Shaw presented a Paper under the title "Vickers Tractor and Associated Ancillary Production".

Tees-Side

The winter lecture programme is now well under way, three well attended and successful meetings being held to date. The first Paper which drew a large audience and involved much discussion was given by Mr. Langdale, one of the Section Committee members. The Section has been further strengthened by the election of Mr. W. G. Roberts.

NORTHERN IRELAND REGION

Northern Ireland

The Northern Ireland Section has arranged a full programme of lectures for the winter session and to date two meetings have been held.

The first lecture in October on "Aircraft Tooling", was given by Mr. S. P. Woodley, M.B.E., of Vickers-Armstrongs Ltd. Mr. Woodley, very ably assisted by Mr. L. G. Burnard, gave an inspired and inspiring address on the present trends and possible future development of tooling in the aircraft industry.

The local aircraft industry was well represented at the lecture and Mr. Woodley's address provoked a lively discussion period.

The second lecture, in November, was given by Mr. H. C. Town on "The Hydraulic Operation of Machine Tools", a subject in which he has both an expert knowledge and experience extending over a long period.

Mr. Town's lecture gave a full and comprehensive picture of the design and application of hydraulics for machine tool operation and control, together with its few limitations. Again, a high level of discussion ensued.

NORTH MIDLANDS REGION

Regional Report

Although much consideration has been given by the five Sections of the North Midlands Region to the recommendation of a representative to sit on the Institution's Materials Handling Committee, the Region is not yet in a position to submit any nominations, but this matter is still under consideration.

The Region is indebted to the Leicester Section for their offer to organise the now traditional one-day Conference in 1958. A Sub-Committee has been formed already to explore preliminary arrangements, and report back to the Regional Committee. It is likely that the Conference next year will be held early in June.

Leicester

The lecture programme is being well received with an average attendance of approximately 50.

At the Section Committee meeting held in October, the Chairman and Committee congratulated Mr. J. France on his election as Chairman of the Education Committee.

At the Section Annual Dinner, held in November, the President of the Institution presented the Leicester Section Committee Prize Award to Mr. P. Barrington, a Student at Loughborough College of Technology.

Local education interests were represented at the Annual Dinner by Mr. S. C. Mason, Director of Education for Leicestershire; and Professor E. A. Stewardson, Head of the Physics Department at Leicester University.

The attendance at the Dinner was an all time record, 224 members and guests attending, including members of the Peterborough Section.

A Sub-Committee has been formed to organise the Regional one-day Conference, which, this time, is being held in Leicester on 7th June, 1958. The theme of the Conference is "Foreign Competition — The Challenge".

Lincoln

During the period under review there have been two lecture meetings held at Lincoln. The first meeting was held

in October, when Mr. J. France, M.I.Mech.E., M.I.Prod.E., M.I.I.A., read a Paper entitled "The Education of the Production Engineer in Industrial Engineering". Mr. F. W. Cooper was also present.

The second meeting was held in November, when Mr. R. W. M. Maling, of I.C.I. Ltd., read a Paper entitled "Management and its Application to Maintenance work".

In November, a Dinner-Dance was held at the Saracen's Head Hotel, Lincoln; this was a successful event and the Section is grateful for all help received from London Office.

Nottingham

The winter session is now in full swing; three lecture meetings have been held, all of which were of interest to members and particularly well attended.

In October, the Section was very pleased to welcome the Education Officer, Mr. F. W. Cooper, who had the opportunity of visiting Nottingham University, the Nottingham and District Technical College, and the works of Ericsson Telephones Ltd. The exchange of views between Mr. Cooper and members of the Section Committee cleared up much ambiguity which had existed for some time.

Despite the loss of members who have taken up employment out of the area, the strength of the Section is maintained by the influx of members from other Sections, and new applications which are steadily flowing in.

Peterborough

The highlight of the past quarter was the visit of the Institution's Education and Technical Officer, Mr. F. W. Cooper, to Peterborough. In addition to visiting a number of local engineering companies, Mr. Cooper attended one of the lectures entitled "Need for Training of Technologists and Technicians" given by Mr. C. Grad, Education Manager for B.T.H. Ltd., Rugby.

The Peterborough Section Committee have decided to award a Section Prize annually for the best Paper submitted by local members. Details, to be finalised, will be circulated later.

NORTH WESTERN REGION

Regional Report

The 1957-1958 lecture sessions within the Region have commenced with attendances at lectures being much better than usual.

Representatives from Preston, Stoke-on-Trent and Manchester have now been appointed to the Materials Handling Group.

Arrangements for the North Western Regional Annual Dinner in February are now completed. The guests attending will be: Mr. M. T. Fuller, Director of the Manchester District Engineering Employers Association; The Lord Mayor of Manchester; Lord Halsbury, President of the Institution; Mr. H. G. Gregory, Chairman of Council; Mr. W. F. S. Woodford, Secretary of the Institution; and Dr. B. V. Bowden, Principal, College of Science and Technology, Manchester.

Liverpool Graduate

The Committee were pleased to see an attendance of over 60 at the last lecture. The Paper, presented by Mr. A. V. Howland in November, was entitled "Jig and Tool Design".

The Committee are most grateful to Mr. B. A. Williams, M.B.E., M.I.Prod.E., for kindness shown in offering facilities for the Section to have a works visit to Williams & Williams Ltd., Chester, on 11th January, 1958. Mr. Williams is Chairman of this firm and is a Past President of the Liverpool Section.

Manchester

The Manchester Section has now formed a Material Utilisation Group, under the Chairmanship of Mr. H. Handforth, M.I.Prod.E. The first meeting was held in December.

The Section Representative on the Materials Handling Group is Mr. H. C. Knott, M.I.Prod.E., M.B.I.M., A.M.I.E.E., M.I.W.M.

The lecture session for 1957-1958 commenced in September with "Engineering Aspects of Automation" given by Mr. A. E. Cowlshaw, A.M.I.Prod.E. — 29 members and visitors attended. The second lecture entitled "Photography in Engineering" by Mr. E. J. Grimwade, of Kodak Ltd., was attended by 65 members and visitors. The third lecture, presented in November, was entitled "Machine Tool Development in the U.S.S.R." by Mr. Norman Stubbs, M.B.E., B.Sc.(Hons.), and Peter Trippe. This was followed by a very interesting discussion — attendance was 65 members and visitors.

Preston

The first lecture of the winter session, "Production of Nuclear Fuels for the Atomic Energy Programme", given by Dr. J. E. Littlechild, at Preston, dealt with an aspect of the Atomic Energy Programme which was of special interest to production engineers. Members and guests present took an active part in the ensuing discussion.

The second lecture, "Modern Welding Processes", was given at Blackburn Technical College by Mr. M. E. Lardge, who drew upon his numerous years of experience in this field to enlighten his audience. An interesting discussion followed. Thanks are due to the Principal for so readily granting facilities for this, the Sections first lecture at the College.

SCOTLAND REGION

Dundee

The December meeting was held jointly with the British Institute of Management, the subject being "The Production Engineer in the Management Team", introduced by Mr. J. Butler, M.I.Prod.E., one of the Section Committee. During the discussion it was agreed that the status of the production engineer would increase.

The Section now look forward to the New Year, commencing with the visit of the President in February.

SOUTHERN REGION

Reading

In keeping with the established practice of holding lectures in different active areas of the Section, an additional meeting has been arranged to be held at Newbury in March.

This will be the inaugural meeting for Newbury and it is hoped that it will promote interest in the activities of the Institution.

Arrangements have been completed for the Third Annual Section Dinner. It will be held on Friday, 18th April, and details will be circulated to members nearer the time.

One of the Committee members, Mr. Mott, is serving on the Materials Handling Group and has undertaken to provide case studies.

SOUTH EASTERN REGION

Regional Report

The Regional competition for Students and Graduates has attracted a number of entries. These are at present being considered by the Regional Committee.

A successful Dinner-Dance was held at the Savoy Hotel in November and was attended by over 300 members and their guests. The Rt. Hon. The Earl of Halsbury was the Guest of Honour and the Region also had the pleasure of having the Chairman of Council, Mr. Gregory, Mr. and Mrs. Woodford, and Mr. and Mrs. Caselton as their guests.

London

The London Section's lecture programme is now well under way. Four lectures have so far been held, including

one at Brighton. The meetings were well attended and gave rise to interesting discussions.

A full and varied programme has been arranged for the new year commencing with "A New Approach to Production Control" on 15th January, and "Achieving Economic Production From Your Press Shop" on 6th February.

The terms of reference for the Brighton Sub-Committee have been discussed, agreed, and are now in operation.

London Graduate

A very successful Weekend School was held at Beatrice Webb House, Dorking, on Saturday and Sunday, 16th - 17th November. The theme was "The European Common Market".

A write-up, together with photographs of the attending members, is in course of preparation with a view to publication in the Journal.

It has also been decided to circulate the minutes of the 1957 Annual General Meeting with the notice convening the 1958 Annual General Meeting. It is hoped by this means to attract more members to the meeting. The members attending will, in addition, be able to take a more active part in the proceedings.

Rochester

The main feature in the last quarter was the joint meeting held with the Graduate Section. This was the first time a joint meeting has been held since the formation of the Graduate Section and the results are not displeasing, consequently it is quite likely to become an annual event. Dr. Seligman's Paper on "The Practical Uses of Radio-Active Isotopes in Industry" was well delivered and received, and the ensuing discussion was very informative.

Applications for membership are still coming in fairly regularly, and it is noticeable that these are now coming from other than immediately local areas. It is hoped that this can be interpreted as a sign of expansion of interest in the Institution.

South Essex

The first meeting of the 1957 - 1958 programme was held in Chelmsford in October, when Sir Gordon Russell presented his Paper on "Pride in Workmanship".

In November, Mr. S. C. Purkiss read a most interesting Paper on "Gear Hobbing and Shaping Techniques". This meeting was the most successful which has been held in the Ilford area and 100 members and visitors were present.

The third meeting of the year was held at Southend, but unfortunately many people were prevented from attending due to bad weather. At this meeting Mr. P. G. Pentz read a Paper on "The Use of Plastics for Making Jigs, Tools and Moulds".

In the last quarterly report, the views of the Committee on the Materials Handling Convention were inaccurately reported and the Committee wish to withdraw these comments unreservedly.

SOUTH WESTERN REGION

Cornwall

Two meetings arranged in the winter programme, 1957 - 1958, have already been held and the attendances have been very encouraging. In October, at the Cornwall Technical College, the Section arranged a Technical Film Evening in conjunction with the South Western Branch of the Institution of Mechanical Engineers and the Cornish Institute of Engineers. Mr. W. E. Butland, of Messrs. Shell-Mex, Plymouth, presented the films and took part in a lively discussion afterwards. The films selected to suit all present, covered a very wide range embracing production, mechanical and geophysical problems.

In November, Mr. W. A. Hawkins, of Messrs. Vaughan Associates Ltd., presented the new George Fischer film on

"Copy Turning". This proved to be a very popular subject, due to developments in local factories, and Mr. Hawkins and his colleague, Mr. F. D. Bullen, answered many involved questions in an admirable manner.

Gloucester

In October, the Section held its first Dinner at The Queen's Hotel, Cheltenham. The guests, who totalled 80, included The Mayor of Cheltenham (Councillor Irving) and Mr. G. R. Pryor. Mr. Pryor gave an interesting address on the aims of the Institution, qualifications for membership and the efforts of the Institution to maintain and raise the standard of technical education.

In November, Dr. D. F. Galloway read his Paper on "The Practical Application of Production Engineering Research" to the Section. He was able to quote some actual financial savings achieved by firms who had been guided by PERA. The meeting was held jointly with the Institute of Cost and Works Accountants.

Western

The 1957 - 1958 session is now well under way and despite inclement weather has got off to a good start.

The meeting at Weston-super-Mare was an outstanding success, partially from the numbers present. To be able to take the Town Hall and hold a meeting of over 150 people was a major achievement and Committee members in Weston are to be congratulated on such a very fine performance.

Once again the Annual Dinner and Dance clashed with the Gauge and Toolmakers' function in London and in consequence numbers were much reduced. Nevertheless, the general standard was maintained and it was a very happy and successful evening. The Section was delighted to receive Mr. Gregory on his first visit to the Western Section.

The first of the lectures in Bristol was given by Mr. Dolphin, Chief Engineer of the Atomic Research Station, Harwell, and it was an excellent lecture on "Engineering in the Field of Atomic Energy".

The joint meeting with the Royal Aeronautical Society had the possibilities of being a complete failure, as the fog was so thick and the trains were so late that it seemed almost certain that Mr. Sargrove could not possibly reach Bristol until everyone had gone home. Although some half-an-hour late, Mr. Sargrove gave an excellent Paper on "The Emergence of Automation as an Evolutionary Process".

WALES REGION

Regional Report

The rather unusual event of the resignation at approximately the same time of both Section Secretaries of the Region, namely, Mr. J. Bolwell (Cardiff) and Mr. H. P. Sanderson (Swansea), due to new business appointments is recorded. The Region offers them both sincere thanks for their past services and best wishes for the future.

The Regional lecture programmes, now 50% completed, have maintained their usual high standard, and the 1958 programme is anticipated with even greater enthusiasm.

The work of organising the one-day Conference due to be held in April, 1958, is proceeding satisfactorily, and the Region is pleased to report that the venue will be Messrs. B.P. Refinery (Llandarcy) Ltd., through the kindness of Mr. R. B. Southall, General Manager.

Arrangements are now in hand for members and their ladies to visit Messrs. Hoover (Washing Machines) Ltd., Merthyr Tydfil, on Wednesday, 26th March, 1958.

Cardiff

Attendances at lecture sessions to date have been very satisfactory and the careful selection of lectures has paid dividends. An outstanding lecture on "Recent Developments

in the Control of Dust" was given by Hr. W. B. Laurie, M.B.E., M.Sc., H.M. Engineering Inspector of Factories, and discussion after the lecture extended well beyond the normal closing time.

An enjoyable evening was had by Committee members and their ladies when they visited the New Theatre, Cardiff, and attended a Dinner at the Park Hotel, Cardiff. The occasion was a presentation to Mr. J. Bolwell, who has resigned from the position of Section Secretary. Mrs. Bolwell was presented with a bouquet and Mr. Bolwell with a silver salver suitably inscribed with the signatures of all the Committee members. Mr. C. L. Griffiths has now accepted the post of Section Secretary.

It is with regret that the resignation of Mr. G. L. Norman, O.B.E., one of our longest service Committee members, has been received. Mr. Norman was one of the first 100 members who joined the Institution when it was formed. His advice and forthright approach will be greatly missed by the Committee and it is hoped he will enjoy a well earned retirement.

The Regional Committee representatives have been very actively engaged with our West Wales colleagues in finalising details for the one-day Convention which is being held next Spring. Information on this Convention will be circulated in due course.

Swansea

The Section held their first lecture of the season in conjunction with the local Productivity Council at the Electrical Showrooms, Swansea, when Mr. D. H. Hitt, Chief Engineer, B.P. Refinery (Llandarcy) Ltd., lectured on "The Role of the Production Engineer in Increased Productivity". The lecture was well attended and of a high standard, with numerous questions from the audience being ably answered by Mr. Hitt.

Mr. H. P. Sanderson, late Secretary of the Section, who has recently been transferred to an executive post with I.C.I. Ltd., at Birmingham, was the chief guest at a Presentation Dinner given in his honour by the Section Committee at the Mackworth Hotel, Swansea. Mr. C. H. Cuniffe, a co-founder with Mr. Sanderson of the Swansea Section, presided. Mr. Cuniffe, in presenting a travelling clock in a crocodile case, together with a cheque from his friends in the Section and Committee members, said that during the 10 years Mr. Sanderson had been Secretary, the Section had developed in stature and numbers far beyond anything expected, largely due to his unfailing energy and ability.

SECTIONS OUTSIDE THE UNITED KINGDOM

Bombay

At the Section meeting held in October, Dr. K. S. Basu, Personnel Director of Messrs. Hindustan Lever Ltd., Bombay, gave a very interesting talk on the "Function of a Personnel Department". Dr. Basu is an authority on this subject in this country and his lecture was very much appreciated by all present.

In November, Mr. R. A. P. Misra, M.I.Prod.E., read a comprehensive Paper on "Modern Furnaces as an Aid to Production". The members present exhibited keen interest on this subject, illustrated by slides.

In December, a very interesting meeting was held in conjunction with the Institute of Industrial Engineers (India) and the Bombay Management Association, when Professor R. F. Bruckart, of Indian Institute of Technology, Kharagpur, India, spoke on "Industrial Engineering — A Challenge and an Opportunity". This meeting was very well attended.

Calcutta

One lecture meeting was held in November, 1957, when a talk entitled "Standards — A Tool for Higher Productivity" was given by Mr. S. K. Sen, Assistant

Director in charge of the Calcutta Branch Office, Indian Standards Institution. The standard of the lecture was high and aroused considerable interest among the members present.

Two Section Committee meetings were held during the months of October and November, and another is due to be held this month.

Melbourne

The highlights of the year for the Melbourne Section took place during the past quarter.

The most important meeting in the history of the Melbourne Section was held in September, when the James N. Kirby Annual Australian Paper was presented by Mr. Walter Scott, Governing Director of W. D. Scott and Company. The Paper, which was entitled "Operation Future — The Engineer in a Changing World", was convincingly presented and enthusiastically received by the 400 members and guests. After the Paper, the Institution's James N. Kirby Medallion was presented to Walter Scott by Mr. W. Gwinnett, President of the Australian Council.

The Annual Meeting and Election of Office Bearers was held on 9th October, 1957. Office Bearers and Committee for the year 1957-1958 remained the same as last year.

After the Annual General Meeting a Paper was presented by Mr. R. G. Giles, B.Sc., B.Ed., an Officer of the Department of Trade. The Paper was entitled "Industrial Research for Manufacturing".

The Annual Dinner was held in November at the University of Melbourne. This Dinner was even more successful than last year. The attendance of members and friends was 175. Guest speaker was Sir Douglas Copeland, Principal of the Australian Administrative Staff College. Sir Douglas Copeland spoke on "The Australian Scene — The Adventure of Development".

A Productivity Working Group has been formed from members of the Melbourne Section. This Group had its first meeting in November, and intends making a study of productivity and ways of improving this in Australia.

Melbourne Graduate

The works visit to General Motors — Holdens Ltd. was postponed until March, 1958, owing to a clash with the James N. Kirby Paper arranged by the Senior Section.

The following films were shown in October: "Strange Interview", a G.M.H. film; "Round Australia Car Trial", a Vacuum Oil feature; "George Fischer Copying Machines and Their Uses". These films were shown in the Vacuum Oil Theatre, Melbourne.

Prior to the showing of films in October the Annual General Meeting was held, at which the Committee and Office Bearers were elected for 1958.

Sydney

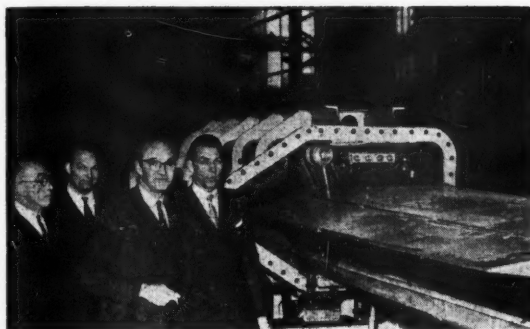
The first Australian Residential Conference was held at Kiama in October. Although attendance was somewhat smaller than anticipated, all who attended expressed great satisfaction, and it is hoped that this has been the first of a series of successful Conferences.

The last lecture of the year was given by Mr. C. N. Watson-Munro on the subject of "Atomic Energy for Industry". As Mr. Watson-Munro is Chief Scientist of the Australian Atomic Energy Commission, and in charge of the erection of the Reactor at Lucas Heights, Sydney, his address was of great general interest.

The Section Annual Dinner, always a highlight of the year's programme, was very well attended. The guest speaker was Dr. S. H. Bastow, Chief Executive Officer of the Commonwealth Scientific and Industrial Research Organisation.

Mr. J. D. Norgard, who delivered the 1956 James N. Kirby Paper, was also a guest, and the opportunity was taken by the Sydney Section Chairman, Mr. S. Downie, to present Mr. Norgard with the Institution's Medal as a token of appreciation.

PRESIDENTIAL VISIT TO SCOTLAND



In February last, the President of the Institution, Lord Halsbury, accompanied by the Secretary, Mr. Woodford, spent three days visiting the Scottish Sections of the Institution. This photograph was taken in the works of Messrs. Brown Bros. at Edinburgh, and shows Lord Halsbury with (from left) Mr. P. H. Lee (Edinburgh Section Committee); Mr. Woodford; and Mr. A. Betts Brown (Scottish Regional Chairman).

LONDON SECTION DINNER



The London Section Stag Dinner, which was held at the Connaught Rooms on 12th February, 1958, achieved its usual success. The President of the Institution was the guest of the Section and was obviously enjoying the occasion when this photograph was taken. In the group are (from left) Mr. R. Telford (South Eastern Regional Chairman); Mr. J. W. Llewellyn-Jones (G. A. Harvey & Son); Mr. G. R. Blakely (London Section Chairman); Lord Halsbury; and Mr. R. J. Whitaker (London Section Honorary Secretary).

WOLVERHAMPTON SECTION ANNUAL DINNER-DANCE



This principal event in the social programme of the Wolverhampton Section took place at the Mount Hotel, Tettenhall, last November, and was a highly successful and well-attended affair.

NEWS OF MEMBERS

Mr. John W. Davies, a Founder Member of the Institution, has recently resigned from the Board of Directors of Ferranti Ltd., Hollinwood. Mr. Davies first joined the firm in 1898 in the tool room. He subsequently became Foreman, followed by appointment to the position of Departmental Works Manager, and in 1924 he became General Works Manager. He was elected to the Board in 1942. Mr. Davies is a Past President of the Manchester District Engineering Employers Association.

Mr. George B. Foote, Member, has left Southern Aluminium Ltd., and has taken up an appointment as Works Manager of R. B. Davies Pty. Ltd., Sydney, New South Wales.

Mr. J. G. Holmes, Member, has recently left this country to take up an appointment with the British Nylon Spinners (Australia) Pty. Ltd., Victoria, Australia.

Mr. A. N. Phipps, Member, has taken up an appointment as Chief Production and Methods Engineer with Hepworth & Grandage Ltd., Bradford.

Mr. C. A. E. Vince, Member, has relinquished his appointment with the Plessey Co. Ltd., and is now General Works Manager of Guest, Keen & Nettlefolds (Midlands) Ltd., Darlaston, South Staffordshire.

Mr. G. W. Brodie, Associate Member, has resigned his appointment of Works Director, H. Widdop & Co. Ltd., Keighley, Yorkshire, to take up an appointment with The Glacier Metal Co., as Manager of the Manchester Service Station.

Mr. C. R. Croucher, Associate Member, has been appointed Works Director in charge of all production and production drawing offices of J. & E. Hall Ltd., Dartford, Kent. Mr. Croucher first joined the Company as an apprentice, 31 years ago.

Mr. J. O. Garvie, Associate Member, who has been acting as Superintendent of H. Frost & Co. Ltd., has now been appointed Production Superintendent, No. 1 Works, Walsall.

Mr. P. Griggs, Associate Member, has relinquished his position as a Management Consultant with Personnel Administration Ltd., and is now General Manager to Velan Engineering Co. Ltd., Leicester.

Mr. C. H. Hunt, Associate Member, has now retired from the Army and has joined The English Electric Co., Stafford, as Assistant to the General Manager.

Mr. A. H. Mills, Associate Member, has taken up an appointment as Manager of the Tool Division of Uddeholm Ltd., Birmingham. He was previously Midlands Assistant Area Manager for Protolite Ltd.

Mr. C. K. W. Scott, Associate Member, has been appointed Lecturer at the Welsh College of Advanced Technology, Cardiff.

Mr. John H. Wilkinson, Associate Member, has relinquished his position as Chief Designer to Messrs. W. E. Sykes Ltd., Staines, to take up a similar position with Messrs. C. B. Powell Ltd., Hove.

Mr. G. D. Evans, Graduate, has now taken up an appointment as an Assistant Technical Officer (Work Study) in the Plastics Division of Imperial Chemical Industries Ltd., Welwyn Garden City, Hertfordshire.

Mr. B. Mansell, Graduate, has now taken up an appointment as a Mechanical Engineer with Canadian Westinghouse Co. Ltd., Hamilton, Ontario, Canada.

Mr. D. Townsend, Graduate, is now employed as Third Assistant Engineer with the Central Electricity Generating Board, Nottingham.

Mr. D. W. Wiles, Graduate, has recently taken up a position as Development Engineer with Alex Pirie & Sons, Bucksburn, Aberdeenshire.

DIARY FOR 1958

9th and 10th April ...	Conference on "Compressed Air in Industry", Camborne, Cornwall.
12th - 21st May ...	Production Conference and Exhibition, Olympia — "Production Fights Inflation".
21st May ...	Fourth Conference of Engineers and those responsible for Standards matters in Industry, London.
27th - 31st August ...	Annual Summer School, Ashorne Hill, Warwickshire. (See Supplement to this Journal.)
13th, 14th, 15th October	Materials Handling Convention, Brighton.
29th October ...	Annual Dinner of the Institution, Dorchester Hotel, London.

Hazleton Memorial Library

ADDITIONS

American Welding Society, New York. **"Welding Handbook."** Section I, 4th edition. Edited by Arthur L. Philips. *New York, the Society*, 1957. 555 pages. Various paging. Illustrated. Diagrams. 72s. (U.K. Distributors: Cleaver-Hume Press.)

This is the first of five volumes which will comprise the 4th edition of the Society's "Welding Handbook". This volume deals with basic principles and data. It is profusely and clearly illustrated by diagrams, photographs and tables. Contents: Standard welding terms (with diagrams); General engineering tables; Fundamentals of welding metallurgy; Properties of welded joints; Factors involved in estimating costs; Inspection of welding; Standard methods for mechanical testing of welds; Statistical control of weld quality; Safe practice in welding and cutting.

Aslib, London. **"Select List of Standard British Scientific and Technical Books."** Edited by L. J. Anthony. 5th edition, revised and enlarged. *London, Aslib*, 1957. 88 pages. 10s. (8s. 6d. to members). Reference. A useful classified list.

Aslib, London. **"Aslib Year Book 1957-1958."** *London, Aslib*, 1957. 194 pages. 12s. 6d. (10s. to members).

Association of British Chemical Manufacturers, London. **"British Chemicals and their Manufacturers"** — the Directory of the Association of British Chemical Manufacturers. *London, the Association*, 1957. 200 pages. Reference.

Association of Engineering and Shipbuilding Draughtsmen, Richmond, Surrey. **"The Balancing of Engines"** by C. C. Pounder. (Paper to the Association.) Session 1929-1930. *London, the Draughtsman Publishing Co.*, 1930. 99 pages. Diagrams.

Bowley, Arthur. **"Elementary Manual of Statistics."** *London, Macdonald and Evans*, 1953. 297 pages. Diagrams. 10s.

British Chemical Plant Manufacturers' Association, London. **"British Chemical Plant."** *London, the Association*, 1957. 402 pages. Reference.

British Institute of Management, London. **"Education and Training in the Field of Management."** *London, the Institute*, 1953. 200 pages. 7s. 6d.

"A survey of relevant courses and subjects at universities, technical and commercial colleges, and colleges of further education in the United Kingdom, and in the examinations of professional and educational bodies."

British Manufacturers of Petroleum Equipment, London — Council. **"British Petroleum Equipment, 1957-1958."** *London, the Council*, 1957. 787 pages. 50s. Reference.

Brownlee, K. A. **"Industrial Experimentation."** 4th edition. (Ministry of Supply — Directorate of Royal Ordnance Factories — Explosives.) *London, H.M.S.O.*, 1949. Reprinted 1956. 94 pages. Diagrams. 7s. 6d.

Produced primarily for the use of those people concerned with pilot plant and plant scale experiments at the Royal Ordnance Factories (Explosives). An account of straightforward significance tests written from the point of view of those persons who have to apply them without full knowledge of their theoretical background.

Canada. National Research Council — Technical Information Service. T.I.S. Reports. No. 43: **"Shaft Sinking by the Freezing Methods."** 1955. 32 pages. No. 47: **"Selected Bibliography on Water Pollution Caused by the Petroleum Industry."** 1956. 13 pages. *Ottawa, the Council*.

"Directory of Opportunities for Qualified Men." *London, Cornmarket, Press*, 1958. 112 pages.

Contents: How executives are chosen; On being interviewed; The earning power of qualifications; Opportunities for professional men in business; Some pros and cons of emigration; Courses — 1958, a list of short full-time courses for qualified men and executives; A list of companies and other organisations which recruit qualified men and women, with descriptions of their work and the opportunities they offer; A list of organisations offering opportunities in the Commonwealth; A classified index of companies and organisations under headings which describe their activities; A qualifications index showing under the different types of qualified personnel the page references to organisations requiring them; A map showing locations referred to in classified index.

"The Engineer Buyers' Guide." *London, Morgan Brothers (Publishers)*, 1958. 888 pages. Reference.

Ferranti Ltd., Edinburgh. **"Conference on Linear Programming — 1954."** *Edinburgh, Ferranti Ltd.*, 1954. 92 pages. Mimeo.

Contents: Linear programming of an air lift, by G. P. M. Heselden and S. Vajda; A problem of transportation, by Mrs. A. Land; An application of dynamic programming, by G. Morton; An experiment in demand analysis; The computation of a diet problem on the Manchester computer, by J. A. C. Brown; Linear programming by the method of leading variables, by E. M. L. Bale; Some experiments on the Manchester computer with the Simplex method, by D. G. Prinz.

Findlay, Ronald M. **"The Art of Administration."** *London, Oliver and Boyd*, 1952. 107 pages.

Forbes, Raymond S. **"Geometric and Mechanical Drawing."** *London, Batsford*, 1957. 136 pages. Diagrams. 12s. 6d.

Judge, A. W. **"Engineering Precision Measurements."** 3rd edition, revised. *London, Chapman and Hall*, 1957. 447 pages. Illustrated. Diagrams. 65s.

Four new chapters have been added to the book since the third edition was published in 1950. Chapters on: slip gauges; straightness and flatness measurements; interferometry methods and surface finish. The sections on engineering fits; screw threads; gear testing; and projection methods, have been amplified and brought into line with modern practice.

Contents: Linear measuring instruments and indicators; Micrometers, verniers and measuring machines; Engineering fits, gauges and methods; Slip gauges and their uses; Screw thread measurements; Internal measurements; The measurement of angles; Comparators; Other optical measurement methods; Measuring microscopes; Flatness and alignment; Interferometry methods; Miscellaneous methods and appliances; Surface finish; Automatic gauging and work sizing. Appendix 1 — The Newall standards of engineering fits. Appendix 2 — List of British Standard Specifications relating to precision measuring instruments and tools.

"Mechanised Work-handling on the Machine Tool." Brighton, Machinery Publishing Company, 1957. 68 pages. Illustrated Diagrams. (Machinery's Yellow Back Series, No. 42.)

"Due to continuous development in machine tools and improvements in tool materials, the output to be expected from any one type of modern machine tool has been increased to such an extent, that the criterion of efficiency is not the time taken to machine a given workpiece, but the time required for placing it in the machine and removing it. Hence during recent years considerable thought has been given to the development of auxiliary devices, which may . . . come to be regarded as part of the machine tool itself, so that the loading and unloading of the workpiece, and presenting it to the cutting tool, may be performed mechanically and automatically . . . In the present book are given examples of a wide range of machines and workpieces that were demonstrated during a Machine Tool show at Olympia . . ."

Contents: Work handling on automatics and lathes; Work handling on grinding machines; Work handling in fine-boring, gear manufacture, and by transfer machine.

Morrow, Robert Lee. **"Motion Economy and Work Measurement."** 2nd edition of Time Study and Motion Economy. New York, Ronald Press, 1957. 468 pages. Diagrams. 63s.

This edition includes chapters on motion study applied to office work, micromotion study and the equipment used; the taking of motion pictures, and their application; and on organisation for methods improvement. Ration delay study and work sampling are fully covered in two chapters.

Office Management Association, London. **"Electronics in the Office: the Practical Application of Electronic Computers and Data Processing Machines to Office Work."** (Papers to O.M.A. Conference, 1957.) 132 pages. Diagrams. 21s.

Contents: How a computer works, by J. G. Thompson (describes how an organisation explained to its staff in a non-technical way, the means of input, storage and output of a typical computer); How we made our investigations, by C. F. Morgan, H. E. C. Nash and J. Worrall (three Papers by speakers from different industries describe how they carried out their investigations before deciding whether or not the new equipment could be justified economically for their company's clerical procedures); How we use a computer, by H. I. Barman, W. G. Jones, Mary S. Munn, L. Gregory, L. Thurgood and A. F. Watson (representatives of four organisations describe their experiences of the use of electronic data processing equipment for their company's clerical procedures).

Rollins, H., and Bell, A. E. **"General Workshop Exercises."** Part I. London, Edward Arnold, 1957. 124 pages. Diagrams. 14s.

"In producing the first collection of General Workshop Exercises, the authors had in mind the practical requirements of a three years' course to the standard of the Intermediate Certificate of the City and Guilds of London Institute in Machine Shop Engineering. The aim was to meet these requirements by the production of useful components which would harness the interest and enthusiasm of the student attending practical workshop classes and . . . provide the National Certificate student with a good basic knowledge of manufacturing processes . . . This book is intended to cover first-year work, and the more elementary portion of second-year work . . ." The exercises are preceded by a section on workshop techniques (preparation for marking out; shaping; drilling; the centre-lathe; soft and hard soldering; heat-treatment of steels).

Rose, T. G., and Farr, Donald E. **"Higher Management Control."** New York and London, McGraw-Hill, 1957. 290 pages. Diagrams. 49s.

The book was developed from three books by T. G. Rose: "Higher Management Control"; "The Internal Finance of Industrial Undertakings"; and "Business Charts". The books have been combined and adapted to meet the needs of American business men. The authors set forth a method for higher control which, they claim, will enable "top management" to get a clear picture of where the business stands, and facilitate decision making. The job of control is defined as: "Recognising, predicting and influencing trends of important phases of the business so that a preconceived goal may be met". The authors claim that their method should help the executive who has not had an accountancy education, and the accountant who often has difficulty in presenting his data to management.

"Set-ups on Automatics." Brighton, Machinery Publishing Company, 1957. 76 pages. Illustrated. Diagrams. (Machinery's Yellow Back Series, No. 41.)

Gives details of interesting set-ups on automatics as demonstrated at the International Machine Tool Exhibition at Olympia.

Contents: Set-ups for single-spindle automatics; Set-ups for multi-spindle automatics; Set-ups for chucking automatics.

Urwick, Lyndall F. **"Sixteen Questions About the Selection and Training of Managers."** London, Urwick Orr and Partners Ltd., 1958. 36 pages. Diagrams. 2s. 6d.

Schrock, Edward M. **"Quality Control and Statistical Methods."** 2nd edition. New York, Reinhold; London, Chapman and Hall, 1957. 246 pages. Diagrams. 54s.

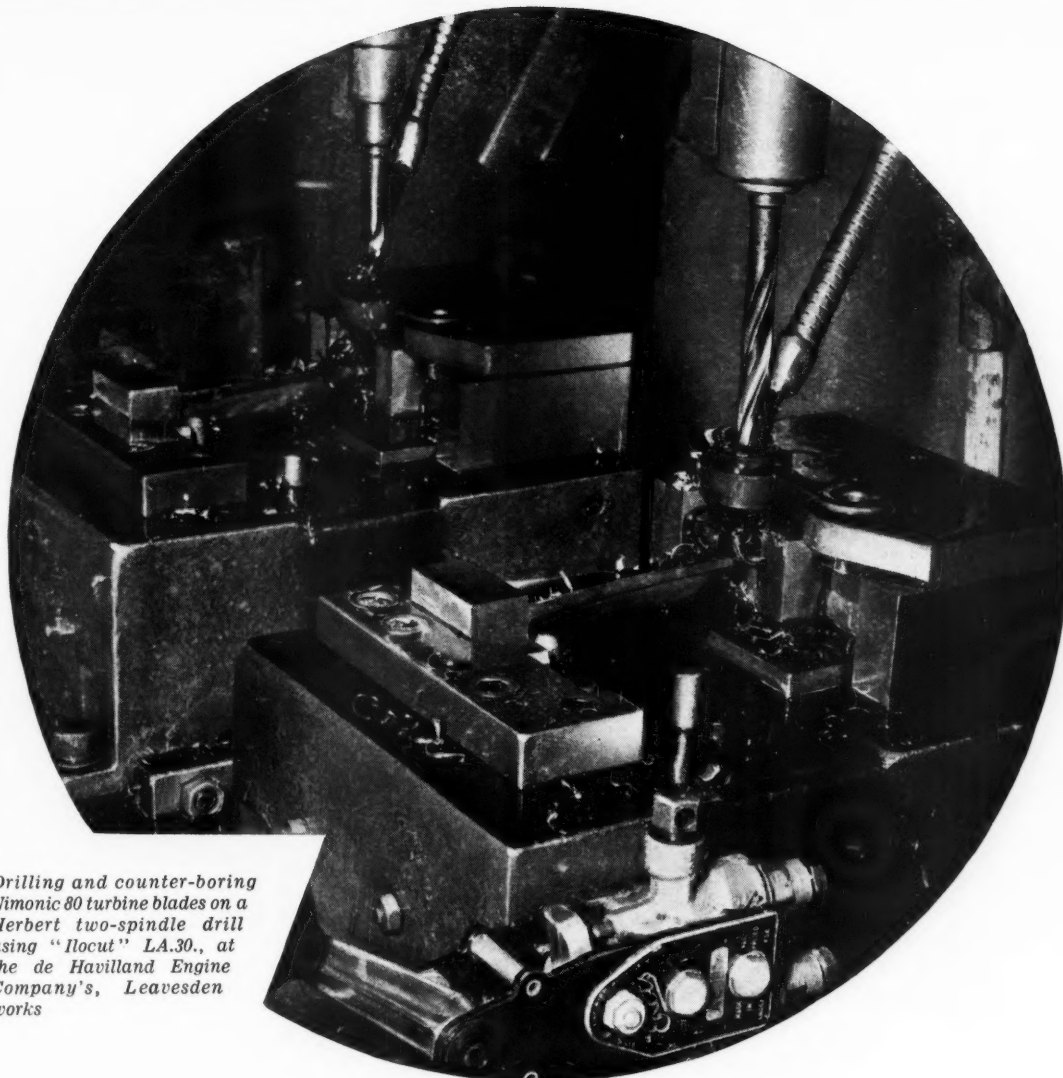
Deals with the purpose, practice, and applications of statistical quality control. This edition includes new material on rapid approximation test of significance, and analysis of variance.

Taylor, George W., and Pierson, Frank C. **"New Concepts in Wage Determination."** New York, London, etc., McGraw-Hill, 1957. 336 pages. 50/6.

The book is sponsored by the Labour Relations Council of the University of Pennsylvania, and contains 11 essays by 12 wage economists, divided into three groups. Contents Part 1 — Viewpoints and environment: An evaluation of wage theory — Wage theory: a management view — Wage determination processes. Part 2 — Structural characteristics and changes: The task of contemporary wage theory — The internal wage structure — The external wage structure — Economic adjustments to changes in wage differentials. Part 3 — National wage movements: The general level of wages — Labour's income share and the labour movement — National wage structure comparisons.

Zinc Development Association, London. **"Progress in Galvanising, 1956."** Edited Proceedings of the Fourth International Galvanising Conference . . . Milan, 1956. London, the Association, 1957. 232 pages. Illustrated. Diagrams. 45s.

Contents: Survey of galvanising practice (a survey of European galvanising practice in 1955); Attack on steel by molten zinc; Construction of galvanising pots; Heating galvanising baths; Work study in galvanising; The galvanising of angles; Galvanising of castings; Galvanising of wire; Painting galvanised steel; New markets for galvanising.



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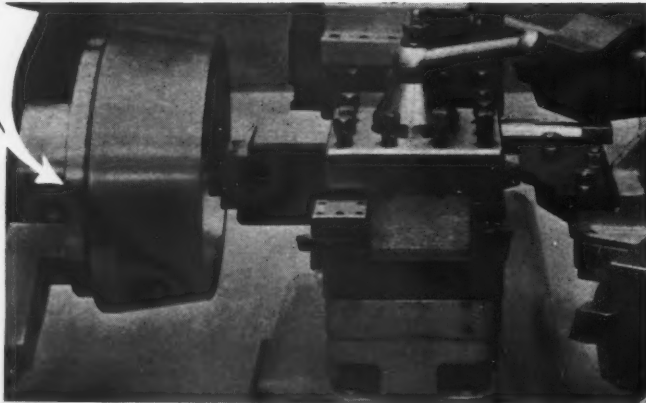
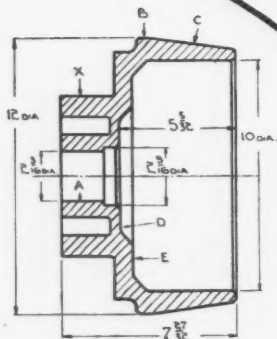
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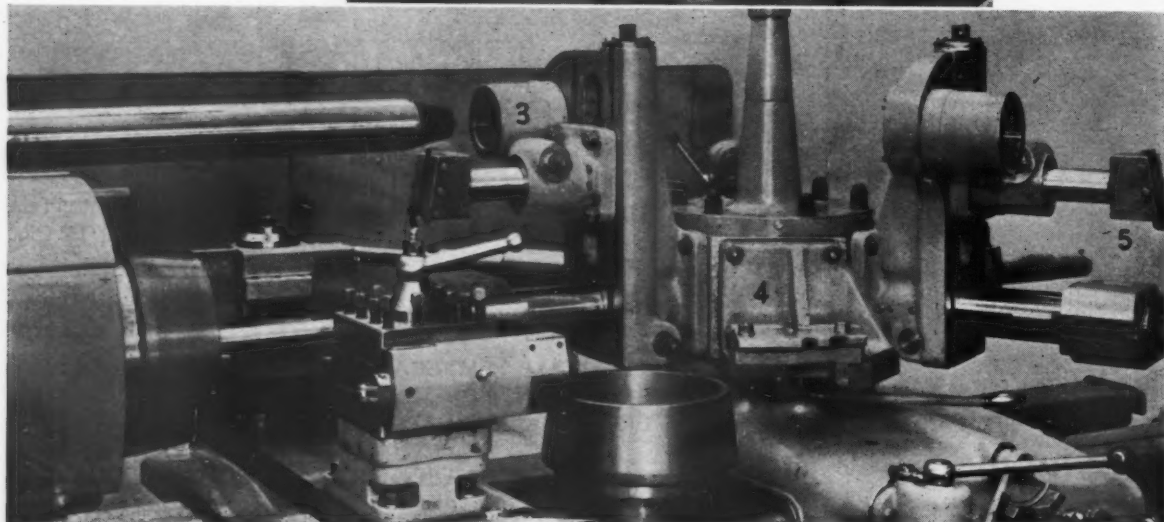


CAST IRON CASTING

Brinell No. 220/228

Floor-to-Floor
Time:
17 1/2 mins. each.

Tungsten Carbide
Cutting Tools



DESCRIPTION OF OPERATION	Tool Position		Spindle Speed R.P.M.	Surface Speed Ft. per Min.	Feed Cuts per inch
	Hex. Turret	Cross-slide			
1. Chuck on X (using Loading Attachment)	1	—	—	—	Hand
2. Rough Bore A & 2 1/8" dia. and Chamfer	2	—	375	260	64
3. Face (2 Cuts)	—	Front 1	93	278	64
4. Rough Bore 10" dia. Rough Knee Turn B and Rough Taper Turn C	3	Rear	75	240	44
5. Contour Face D & E (Rough & Finish)	4	Front 3	93/125	242/325	64
6. Finish Bore 10" Finish Knee Turn B and Finish Taper Turn C and Chamfer 10" dia.	5	Rear	125	390	64
7. Chamfer Outside Dias.	—	Front 2	125	390	Hand
8. Finish Microbore 2 3/8" dia.	6	—	580	333	88
9. Remove (using Attachment)	1	—	—	—	Hand

Ward

No. 10 TURRET LATHE

FITTED WITH 18in TUDOR 3-JAW CHUCK

H. W. WARD & CO LTD

SELLY OAK
BIRMINGHAM 29
TELEPHONE SELLY OAK 1131

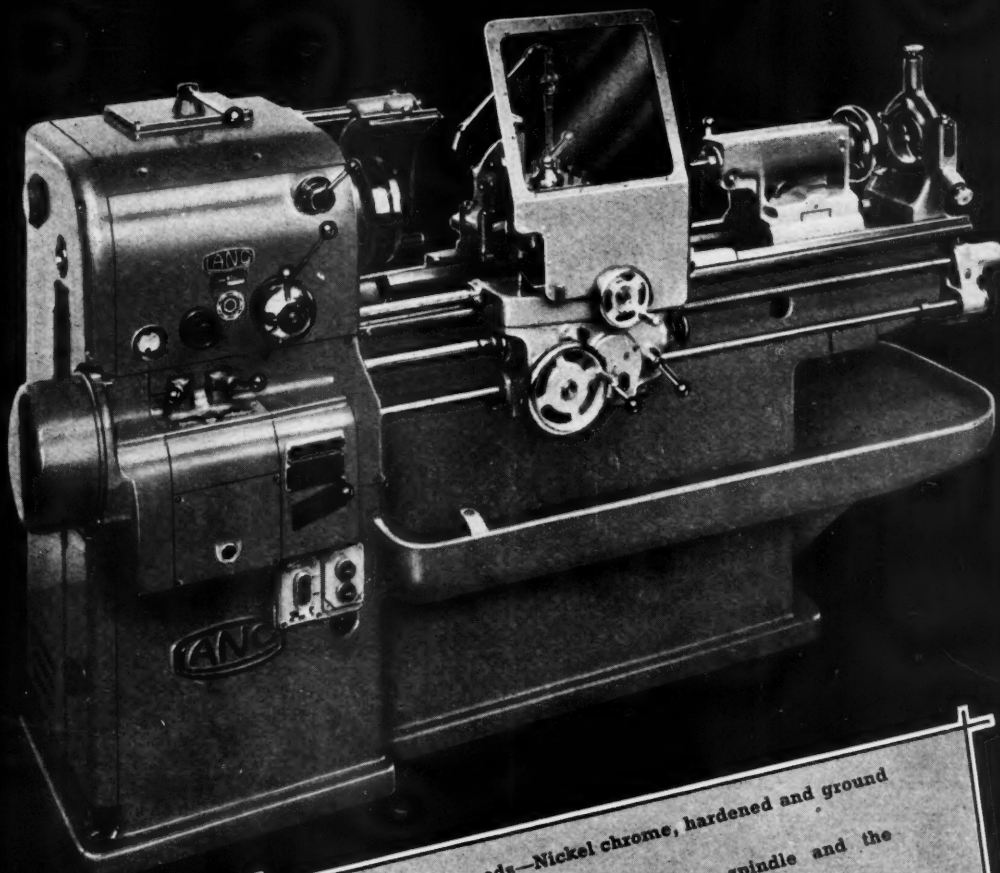




**sliding surfacing and
screwcutting lathes.**

13" and 17" swing.

model J6.



- 12 Spindle speeds—Nickel chrome, hardened and ground gears.
- Pre-loaded spherical roller bearing spindle and the bearings pump lubricated with filtered oil.
- Totally enclosed multi-feed gear-box.
- Pump lubrication to feed gear-box, apron and saddle.
- Hardened steel wear strips on under slideway faces of saddle.
- All controls conveniently grouped.

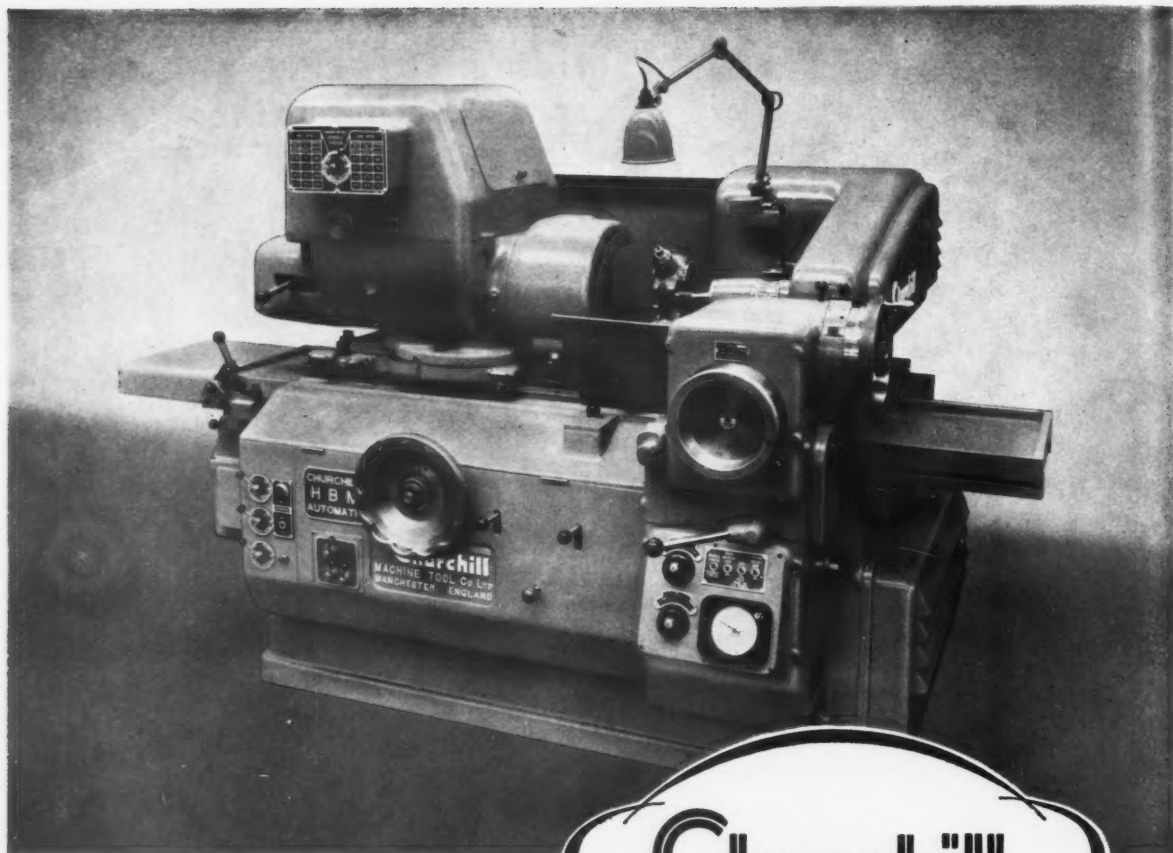


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ASSOCIATED BRITISH MACHINE
TOOL MAKERS LIMITED
17 GROSVENOR GARDENS SW1

JOHN LANG & SONS LTD.

JOHNSTONE RENFREWSHIRE SCOTLAND

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Churchill

HBM AUTOMATIC SIZING INTERNAL GRINDING MACHINE

CHURCHILL Automatic Sizing Internal Grinding Machines are renowned for their accuracy and speed of production. The extensive experience gained from supplying very many machines has been fully utilised in the Model 'HBM' to ensure highly efficient operation over a wide range of work.

Single or double automatic cycle operation according to work.
Plunge cut and traverse grinding.
Feed accelerator reduces production time.
Exceptionally wide range of roughing and finishing feeds.
Diminishing rate of feed to zero with variable electric dwell at size position.
Adjustable oscillation for building-up finish on blind end and open short length bores.
Hand feed to dead stop for plain internal grinding.
Operational safety — provision for immediate interruption of automatic cycle for emergency run-out — enclosing of dogs and plungers eliminates "finger traps".
Can be equipped for combined hole and face grinding.



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Telegrams : Churchale, Manchester.

Export Sales Organisation : Associated British Machine Tool Makers Ltd., London,
Branches and Agents.

Home Selling Agents : Charles Churchill & Co. Ltd., Birmingham and Branches.

PRECISION *plus* PRODUCTION

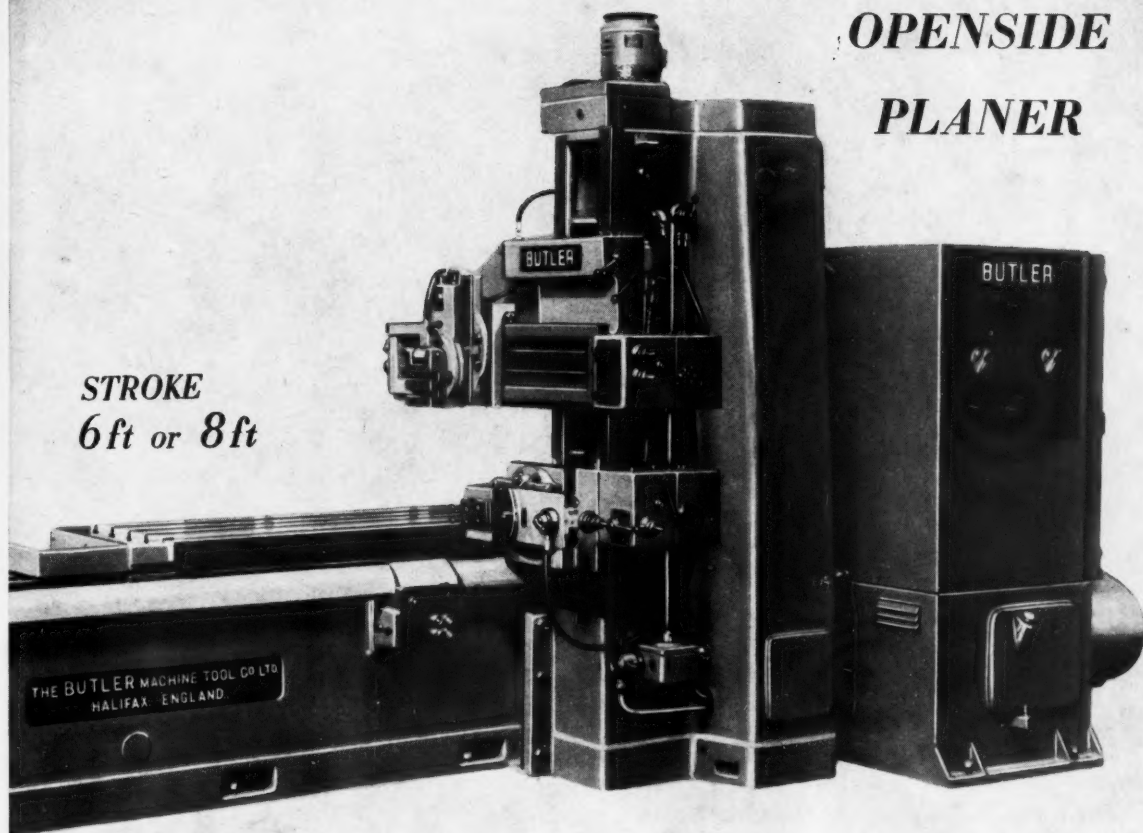
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HYDRAULIC 2 ft 6 in x 2 ft 6 in

**OPENSIDE
PLANNER**

**STROKE
6 ft or 8 ft**



Maximum stroke 6 ft or 8 ft

15 h.p. self-contained drive

Return speeds 36 to 136 ft/min

Hydraulic tool relief

Work capacity 30 in. wide x 30 in. high
under cross-slide

Cutting speeds, low, 20 to 60 ft/min

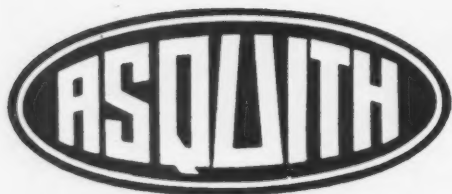
Cutting speeds, high, 68 to 120 ft/min

Feeds (10 rates) 0.02 in. to 0.20 in/min



The **BUTLER MACHINE TOOL CO LTD**
HALIFAX **TELEPHONE 61641** **ENGLAND**

**PLANERS
SHAPERS
SLOTTERS**



STATIC MILLING UNIT TYPE MMH 150



SPECIFICATION

10 '20 h.p. STATIC MILLING UNIT, Type MMH 150

10 h.p. @ 108 r.p.m.

Speed range 108-490 r.p.m.

26 h.p. @ 350 r.p.m.

33 h.p. @ 490 r.p.m.

Min. revs. for 20 h.p. 250 r.p.m.

Spindle Nose,
No. 50 standard taper and drive.

A simple, economic unit for face milling

This unit is of very robust construction and incorporates an orthodox milling machine spindle in an adjustable quill mounting. The spindle is mounted in anti-friction bearings, the front bearing having a tapered inner race to give facility for separate adjustment for radial and thrust loads.

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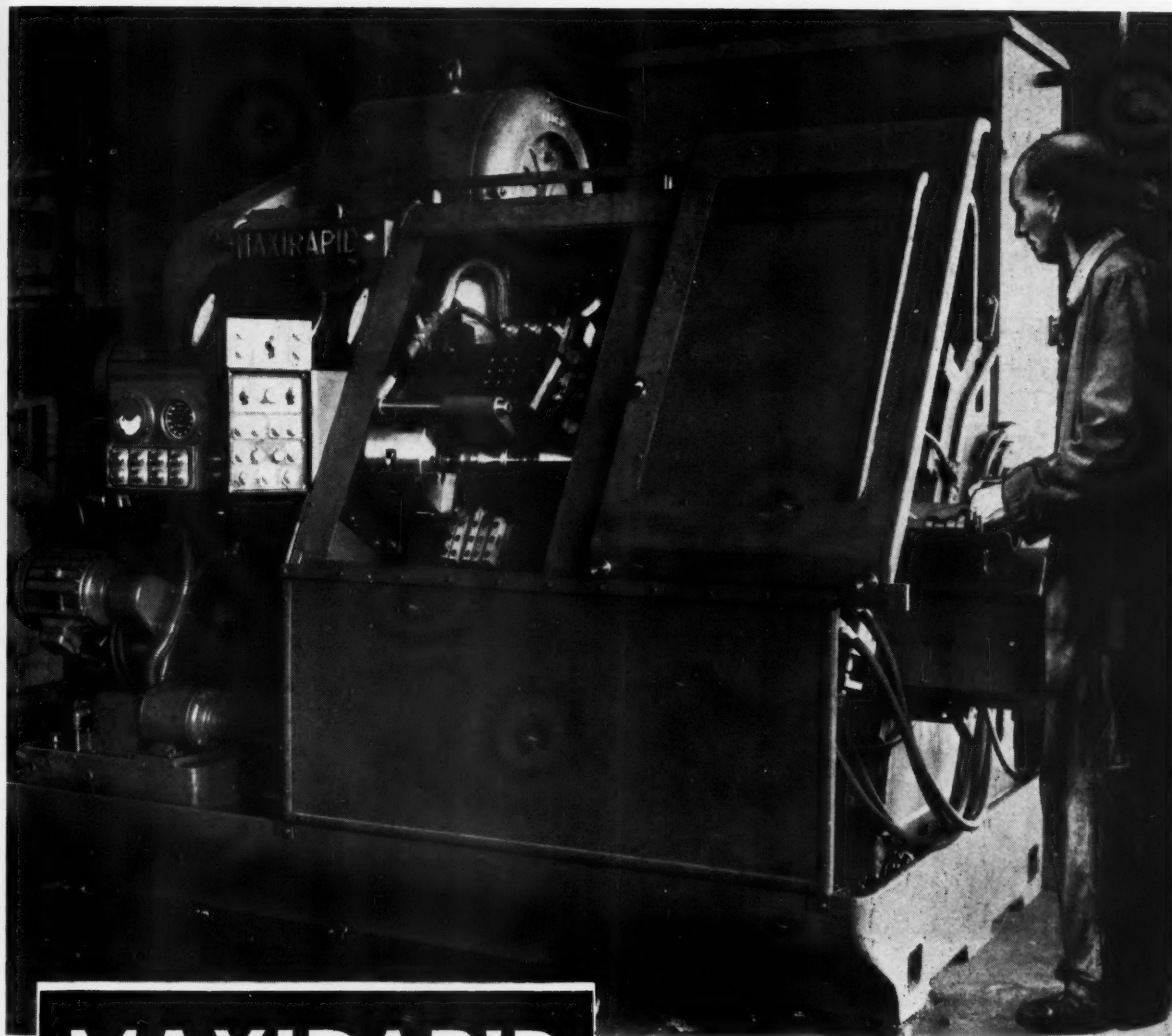
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A276

The multi-tool lathe with automatic loading!



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for fast, high-output production

An exceptionally powerful and rigid machine specifically designed with angular bed for heavy metal removal and fast, accurate, long run production. Provision can be made for automatic loading and unloading of components.

In the above illustration this is accomplished by feed chutes from the right-hand end of the machine and a hydraulic auxiliary slide unit carrying loading and

unloading shoes which exchange the component on the completion of each machining cycle.

Maximum swing over bed 17 in. Maximum distance between centres 24 in. Supplied with 25, 35 or 50 h.p. motor.

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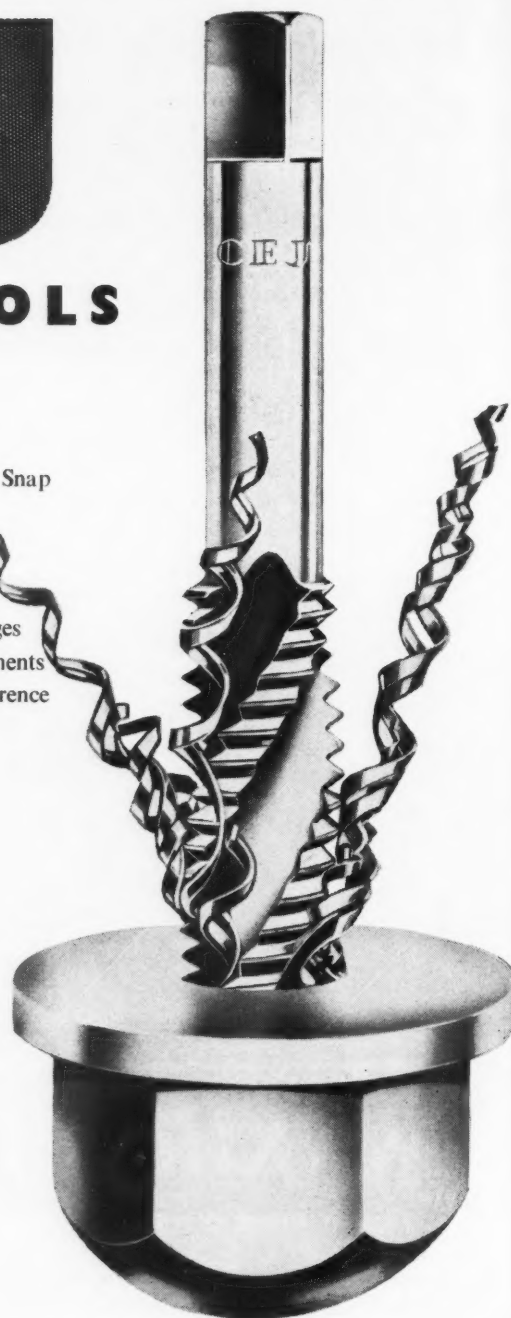
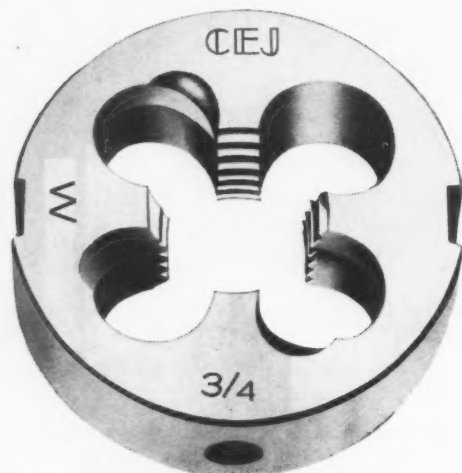
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CEJ

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CEJ PRODUCTS

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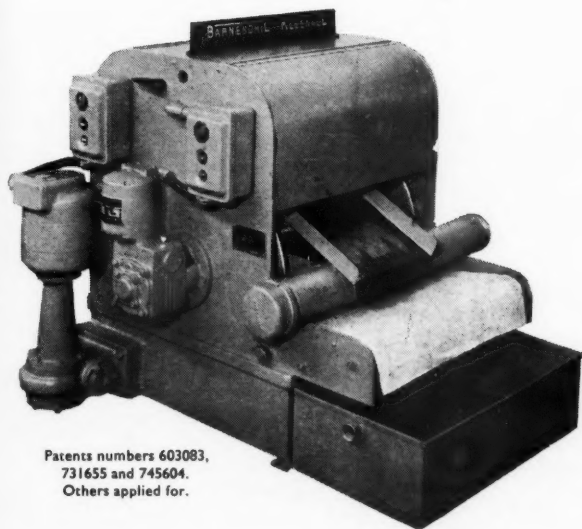
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Combines Magnetic Separation
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... and CLEAN Coolants Give You



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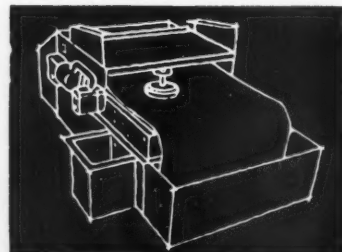
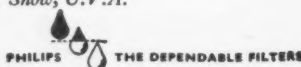
Operators and employers both appreciate the advantages of a Philips Universal Clarifier. It means a cleaner coolant, reduced maintenance time, and a better surface finish for the product. For higher efficiency all round and a marked saving in costs, specify a Philips Universal Clarifier every time you buy a grinder. Philips technical staff are available throughout the country to give advice and assistance. Please write or 'phone for further information.

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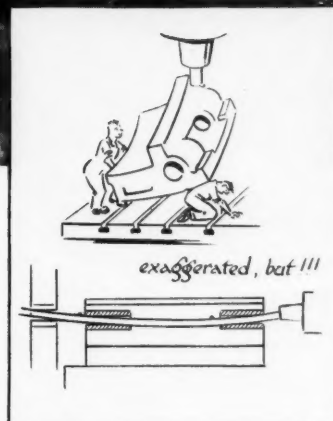
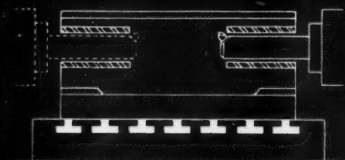
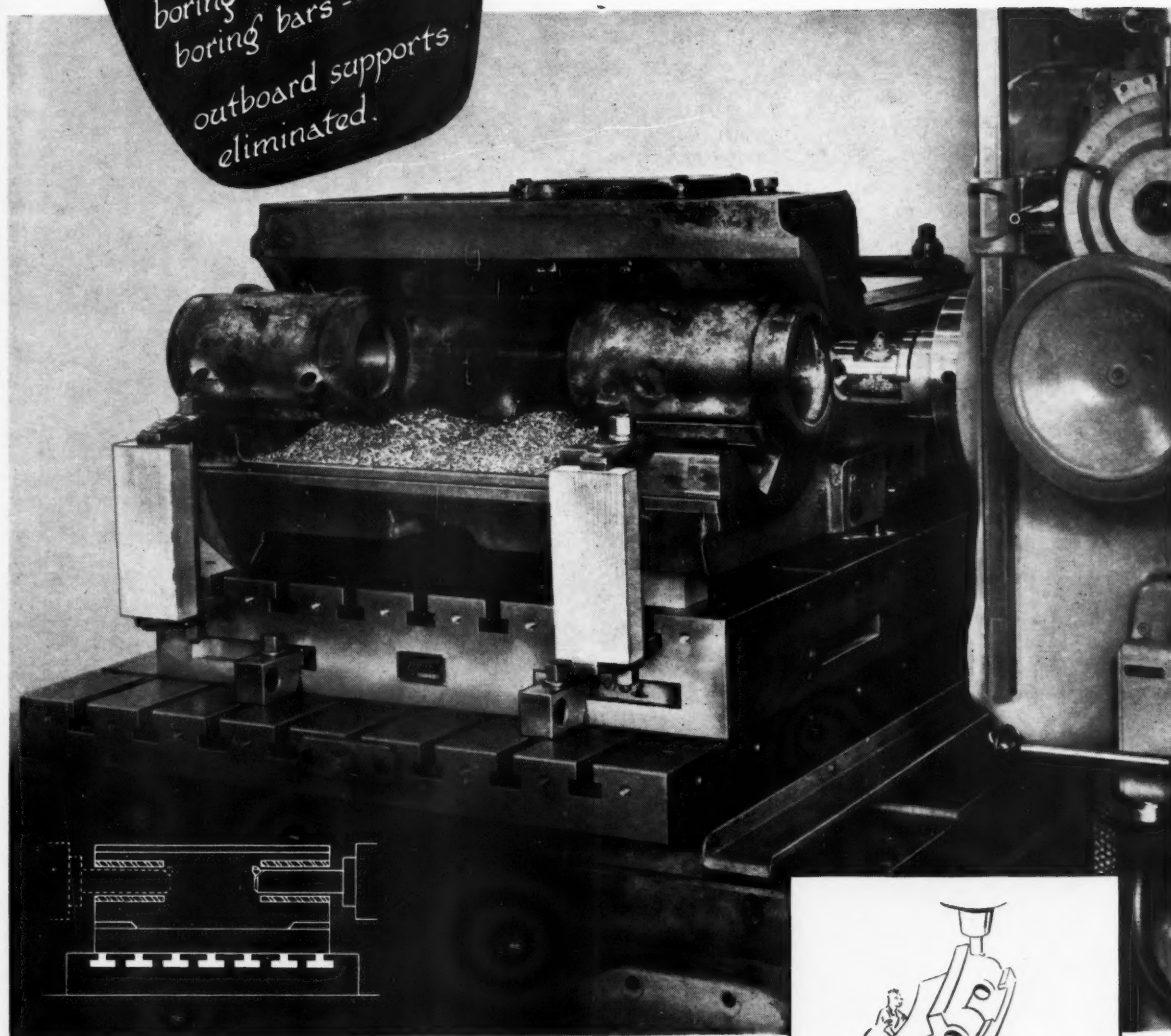


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Universal Clarifier

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LTD., COVENTRY - FACTORED DIVISION, RED LANE WORKS

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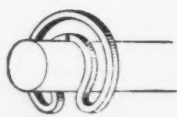


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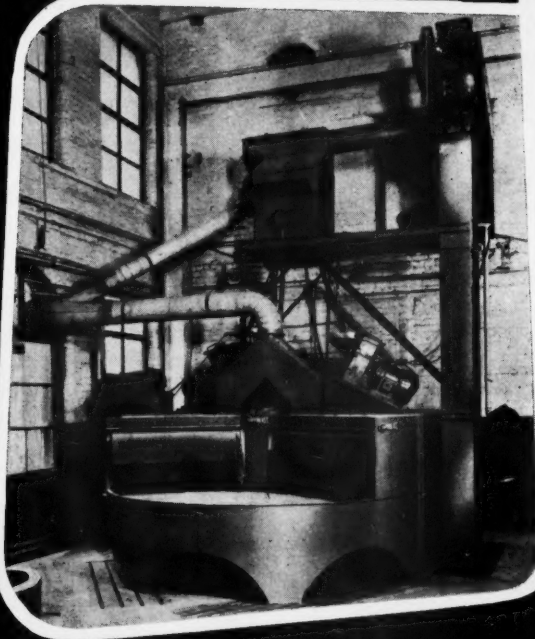
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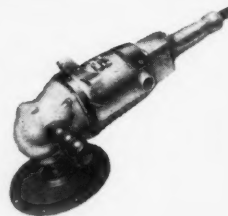
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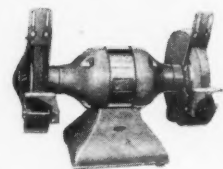
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Many years' research and the evolving of the most advanced processing techniques enabled Wm. Jessop & Sons Ltd. to produce Titanium commercially in the largest ingots available in Europe. The result is the Hylite range of Titanium alloys, largely used in the aircraft industry, and now providing the ideal material for many other fabricating industries

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the steels that are
melted in vacuum
by JESSOPP

For full details send
for this important
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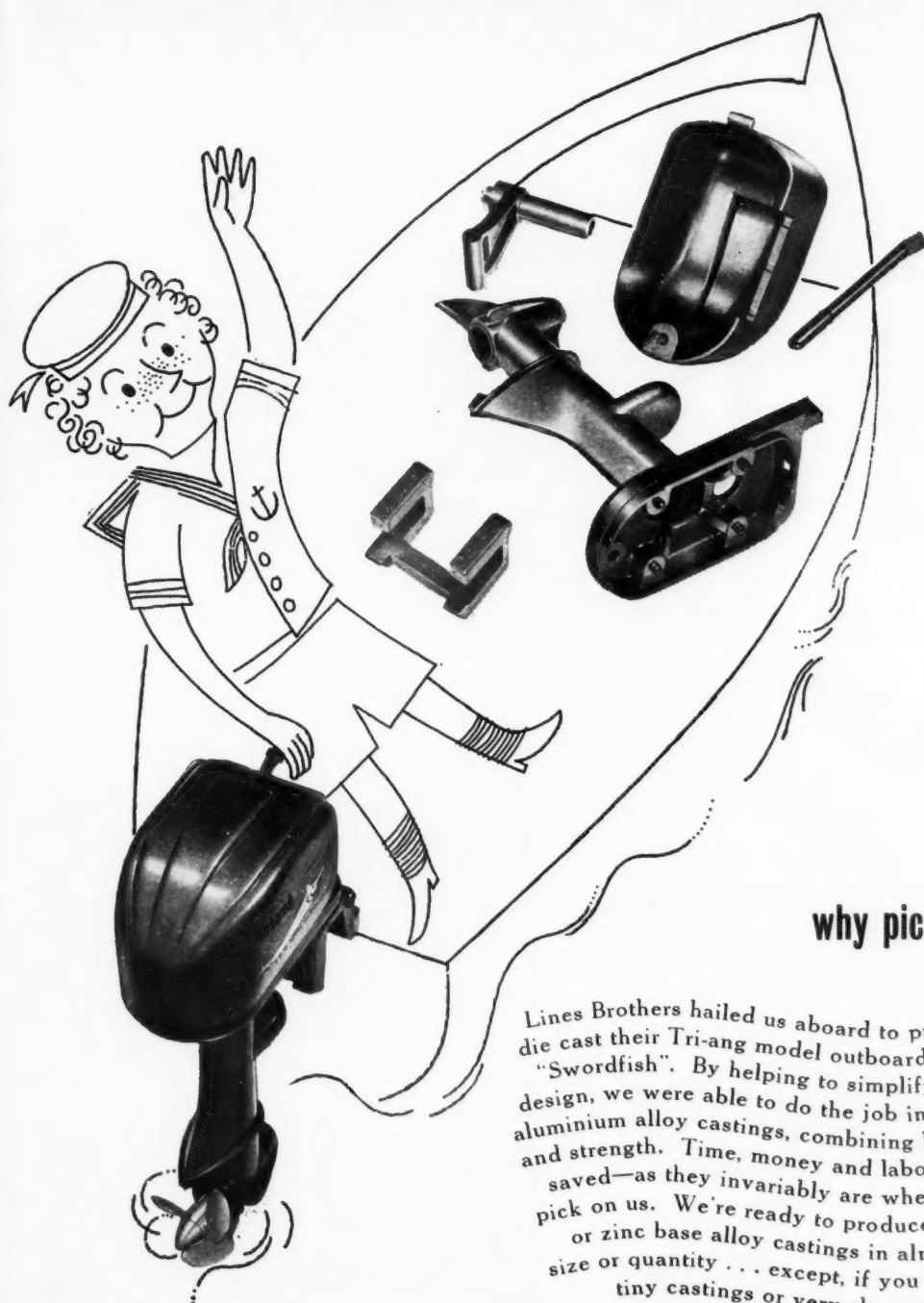


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are made with lift capacities varying from 120 lbs. to 1,000 lbs. *Variable speed* of operation is obtained simply by amount of trigger pressure, and *balance effect* is incorporated for easy load positioning. They cannot be damaged by overloading.

*Instant operation —
by trigger pressure **

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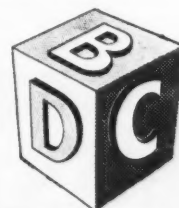
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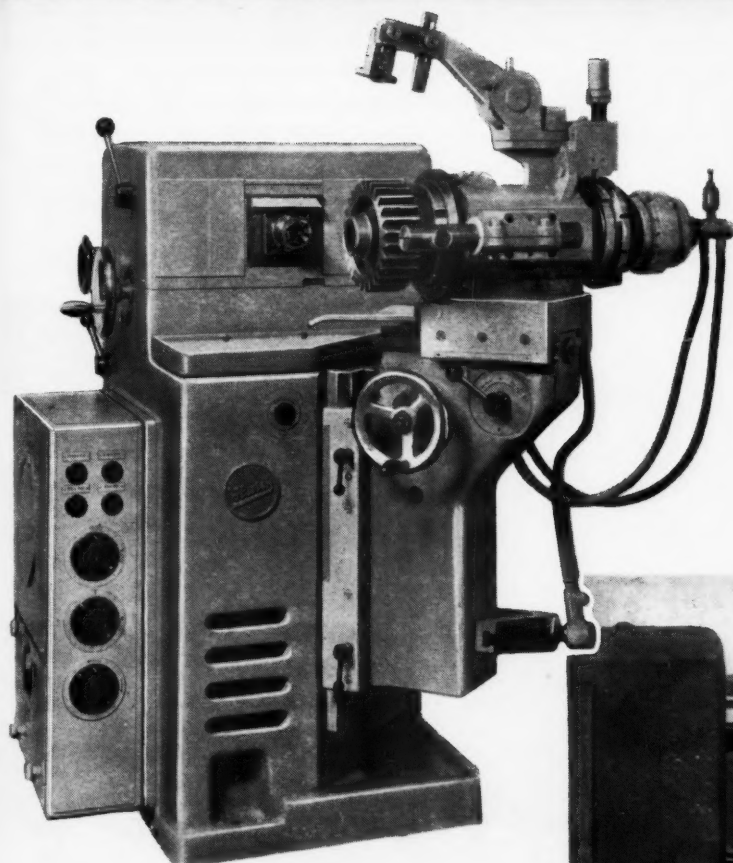
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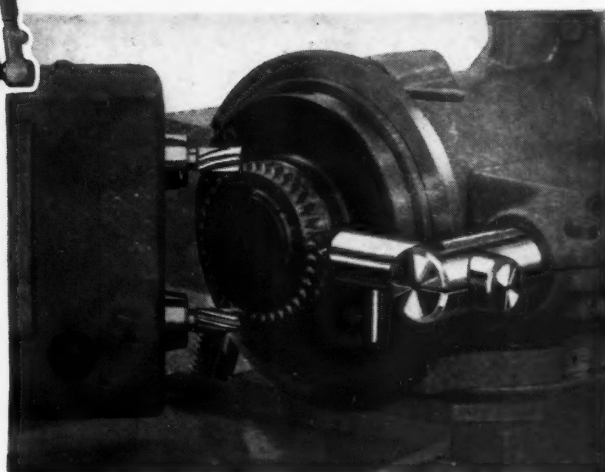
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GEAR TOOTH ROUNDING & DE-BURRING MACHINES

● **TWO SPINDLE HEAD AVAILABLE
FOR VOLUME PRODUCTION**



Fast approach of bell-type cutter, self indexing after reaching pre-set depth and automatic stopping on completion of cycle, make the HURTH Model ZK4 an ideal machine for batch work on spur and helical gears, starter rings, clutches, etc. Maximum work-piece dia: 12". Range of teeth rounded: chamfered or de-burred 25-6 D.P., 7-110 teeth per gear. Speeds up to 120 teeth per minute.

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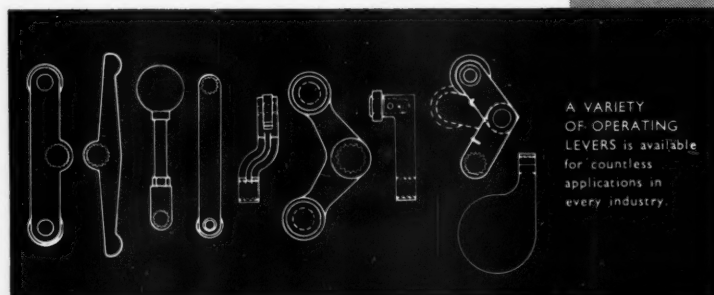
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limit switch

For all heavy duty limit switch applications, particularly those to withstand conditions of extreme severity, there is a suitable B.S.A. ACME SNAP-LOCK of either water, oil, and dust proof, or flameproof versions. The superiority of this switch is due largely to the simplicity but ruggedness of its mechanical and electrical units contained in separate compartments within a robust housing. Unique Snap-Lock design ensures self-wiping quick make and break, positive contact, maximum resistance to wear, and accurate repetitive tripping.



A VARIETY OF OPERATING LEVERS is available for countless applications in every industry.

NEUTRAL POSITION

These limit switches are available in Neutral Position versions. Spring-loaded devices return the operating lever to the central (neutral) position. One or both of the springs are removable for various circuit arrangements. A third spring is supplied for converting to one normally made and one normally broken circuit.

**B.S.A.
ACME**

MADE UNDER LICENCE FROM
NATIONAL ACME CO. U.S.A.

snap-lock

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Sole Agents Gt. Britain :

BURTON GRIFFITHS & CO. LTD.

Snap-Lock Division : 93 Albert Embankment, London, S.E.11

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STANDARD

WATER, OIL & DUST PROOF



FLAMEPROOF

SINGLE OR DOUBLE ENTRY



3574 GROUP I
3575 GROUP II

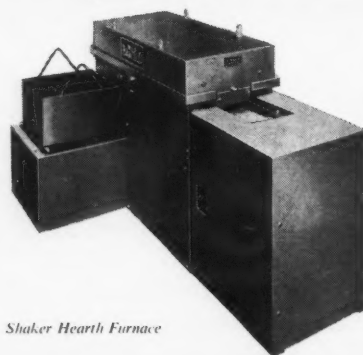
STANDARD

Single pole, double break, double throw, operates with either circuit normally open with other closed, or maintaining in either position, or available with central neutral position. Heavy die-cast case. Water, oil and dust proof. Conduit $\frac{1}{2}$ " in. B.S., or No. 3 Admiralty Pattern Cable gland entry. Two-screw side mounting or backplate mounting in two styles, or Tandem style (back to back mounting). Operating lever position adjustable in 7.5 deg. increments through 82.5 deg. either way from normal.

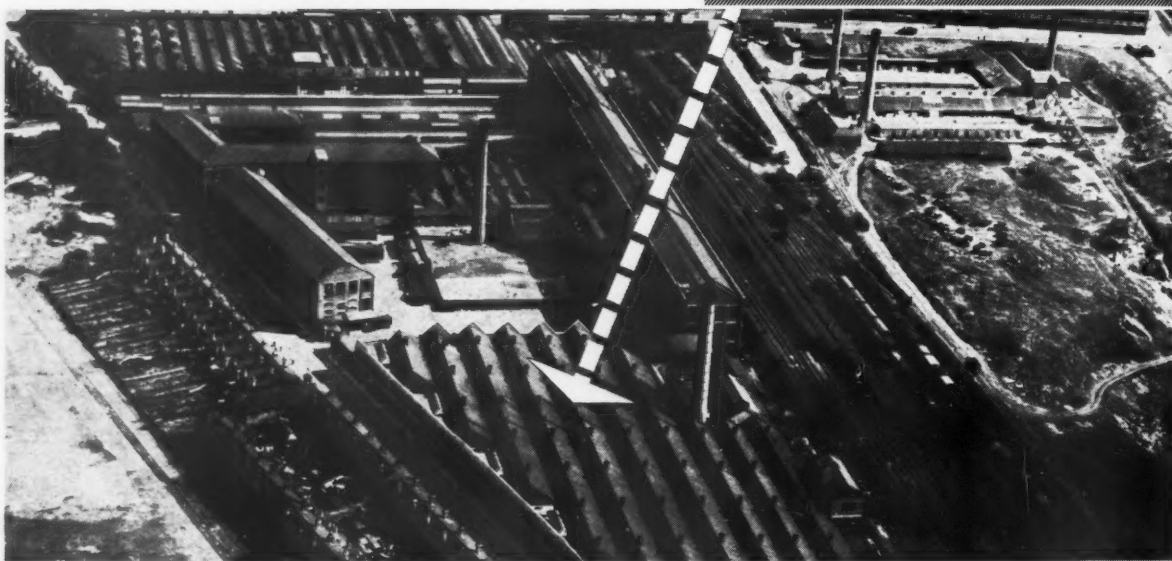
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Buxton certificates No. 3574 (Group I) No. 3575 (Groups II and III gases). Meehanite iron castings. Self wiping solid silver contacts. Interchangeable plugs and sockets. Internal mechanism removable as a unit for servicing. Single SWA cable entry (standard); double entry if required. Operating lever position adjustable in 7.5 deg. increments through 360 deg. Single pole, double break, having one normally closed and one normally open circuit. Available with central neutral position.

Fit Wild-Barfield furnaces into *your* production line



Shaker Hearth Furnace



A Wild-Barfield furnace will bring immediate advantages. It speeds up production and helps to cut costs by eliminating delays and wasteful handling. Built to the highest standards of workmanship, these furnaces offer consistent results and minimum maintenance. The Wild-Barfield Research Department is available at all times to advise you on your heat-treatment problems.

Continuous and batch type furnaces for :

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WILD - BARFIELD ELECTRIC FURNACES LIMITED

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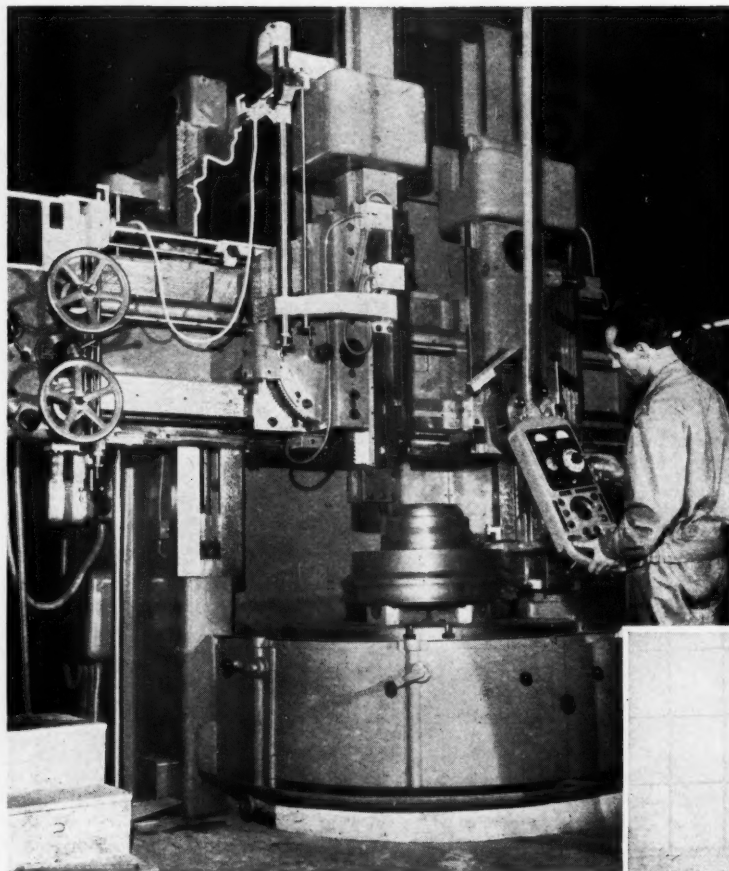
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WB 61

SKODA

Vertical Boring and Turning Mill

Model SK 12



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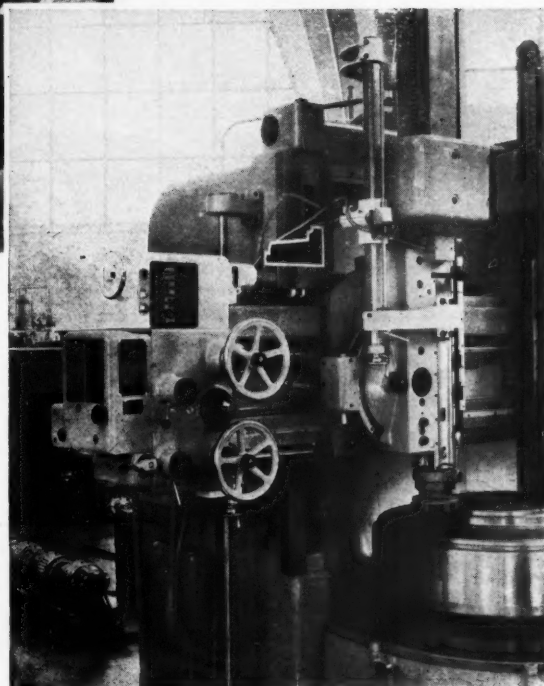
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Infinitely variable high table speeds

Anti-friction bearings fitted to spindle

Drive through variable speed commutator motor

Cross-rail automatically clamped and unclamped when raising or lowering



BRIEF SPECIFICATION

Maximum swing with side head	49 in.
Maximum swing without side head	53 in.
Maximum distance between table and rail head toolholder	39 in.
Table Diameter	46½ in.
Infinitely variable speed from	3.55-150 r.p.m.
Variable speed motor output	27 kW
Weight of machine	15 ton 12 cwt. approx.



Full Details from Sole Agents

The Selson Machine Tool Co. Ltd.

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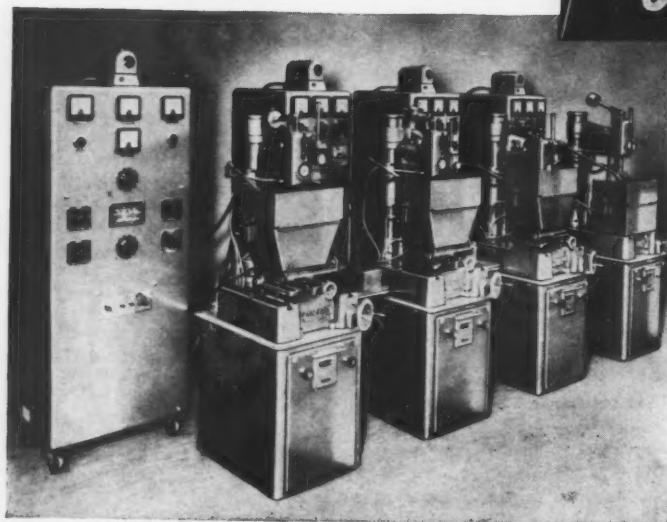
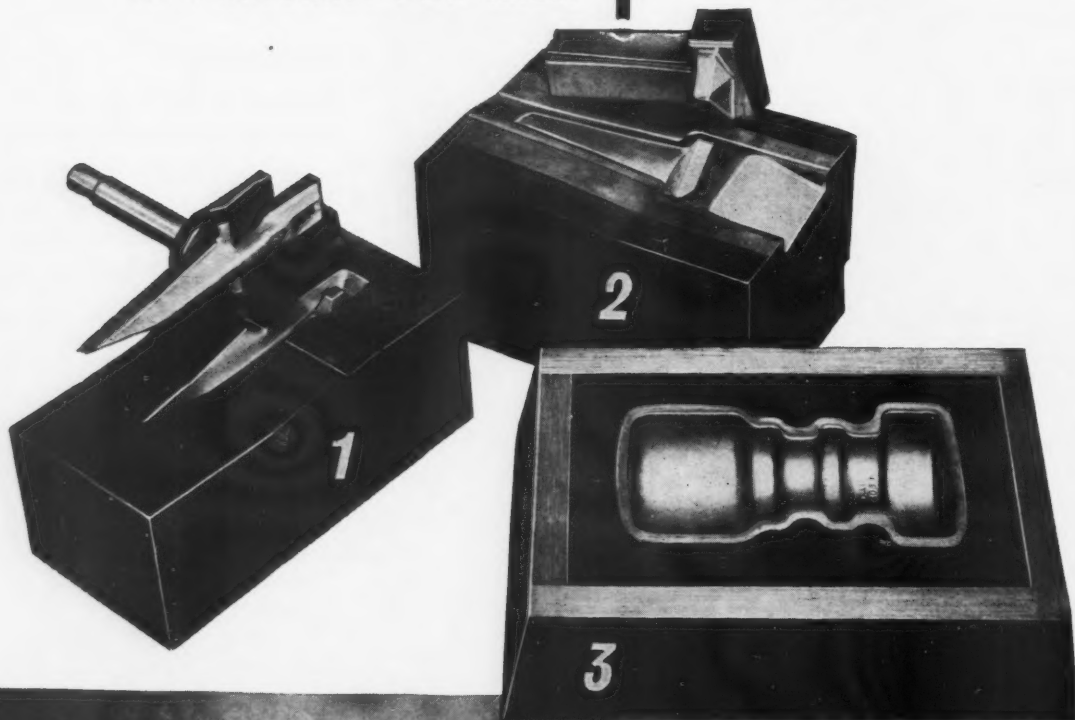
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Mk III Model

6.5 kW



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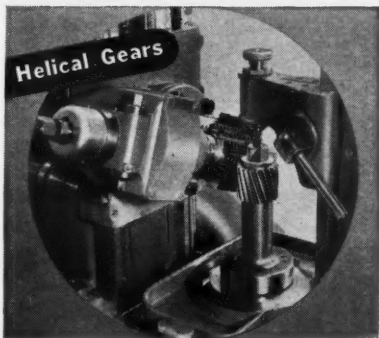
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**EARLY
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8" dia. by 7" face by 14 D.P.

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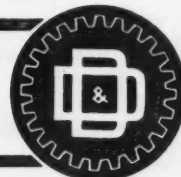
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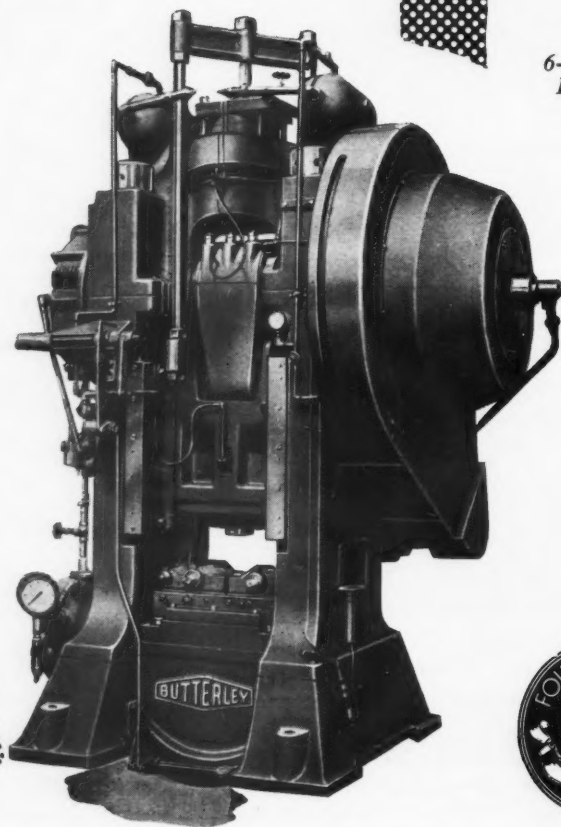
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Forging Press
(120 tons)



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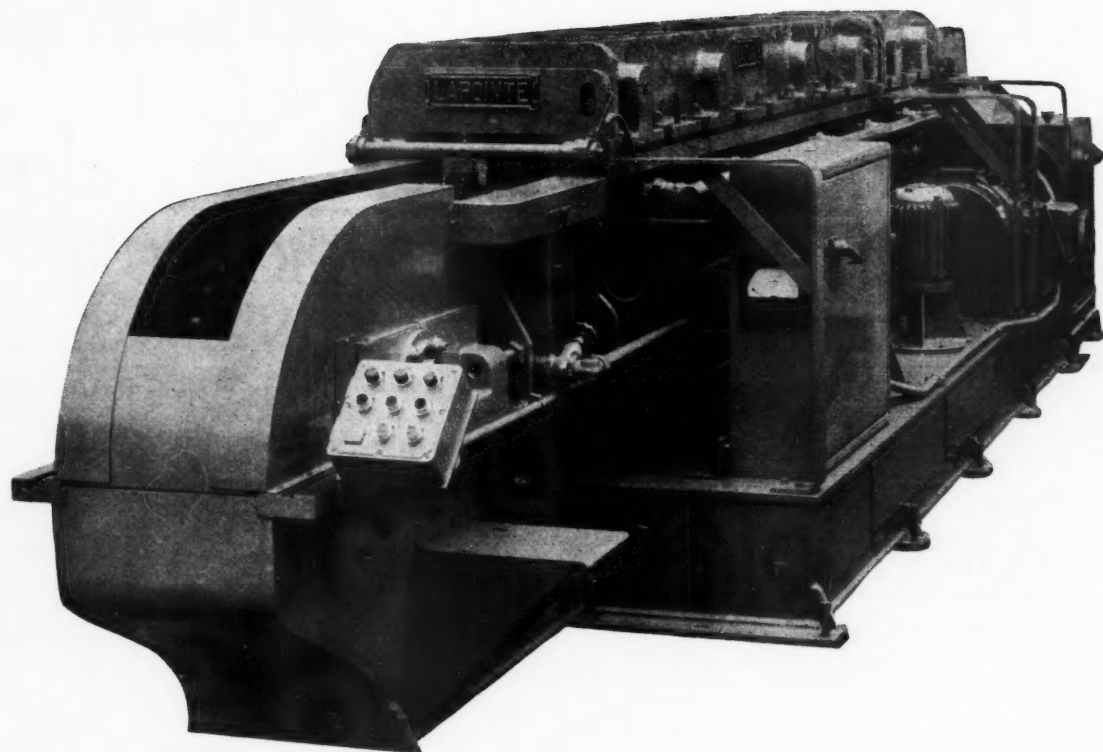


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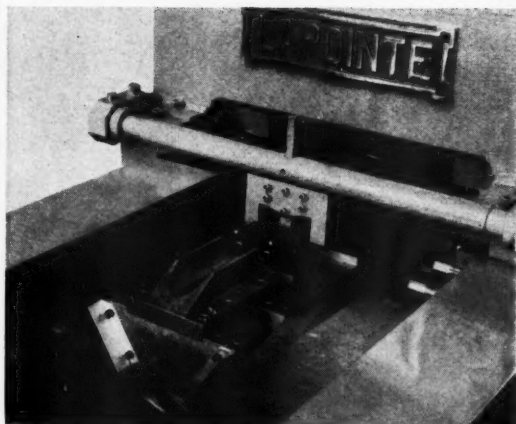
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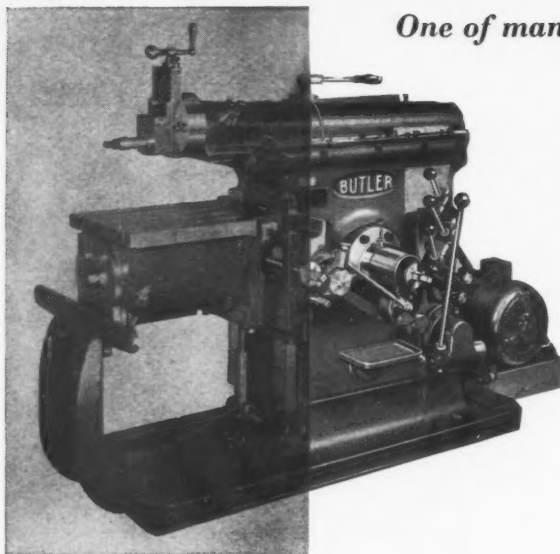


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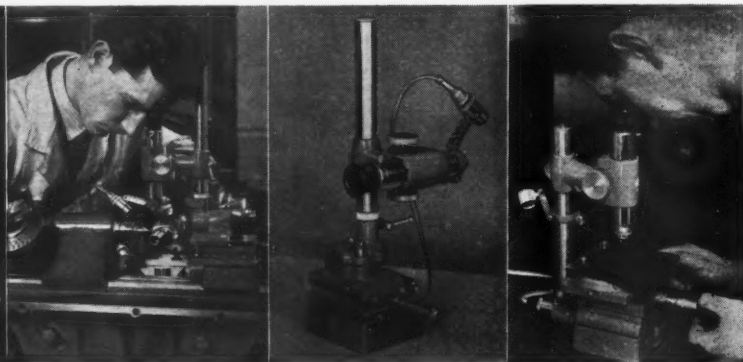
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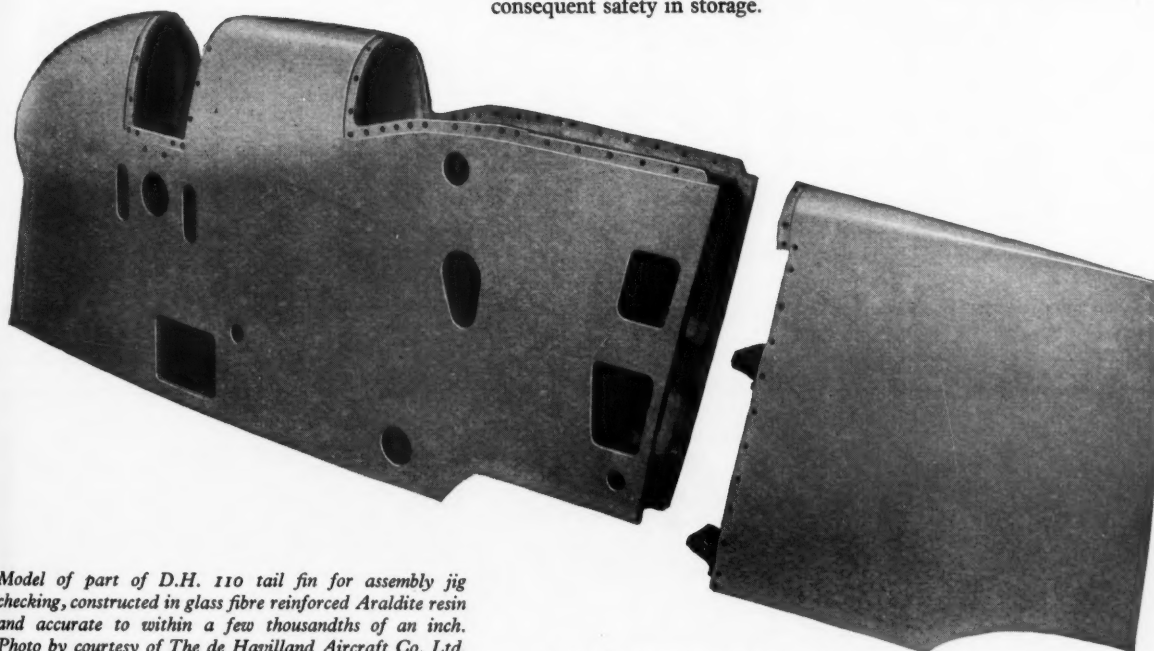
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Model of part of D.H. 110 tail fin for assembly jig checking, constructed in glass fibre reinforced Araldite resin and accurate to within a few thousandths of an inch. Photo by courtesy of The de Havilland Aircraft Co. Ltd.

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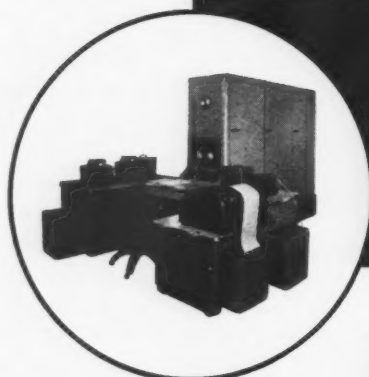
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AP327

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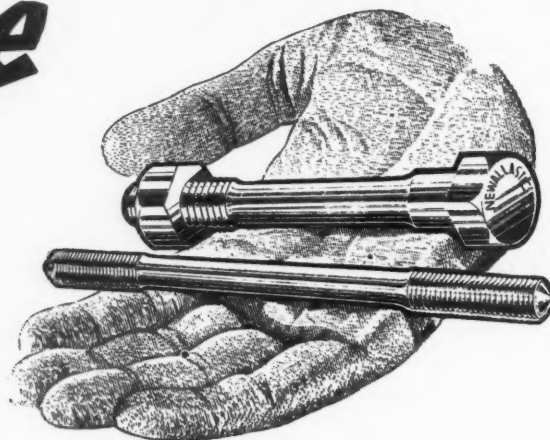
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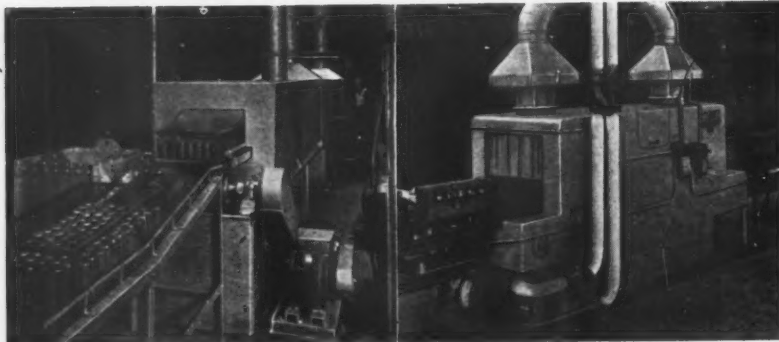
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A model 'A' machine washing parts of motor car engines prior to assembly.

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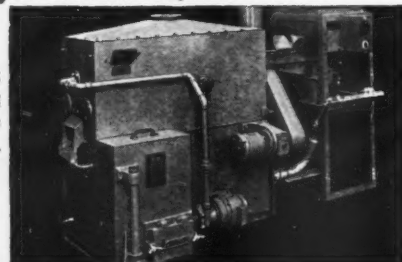


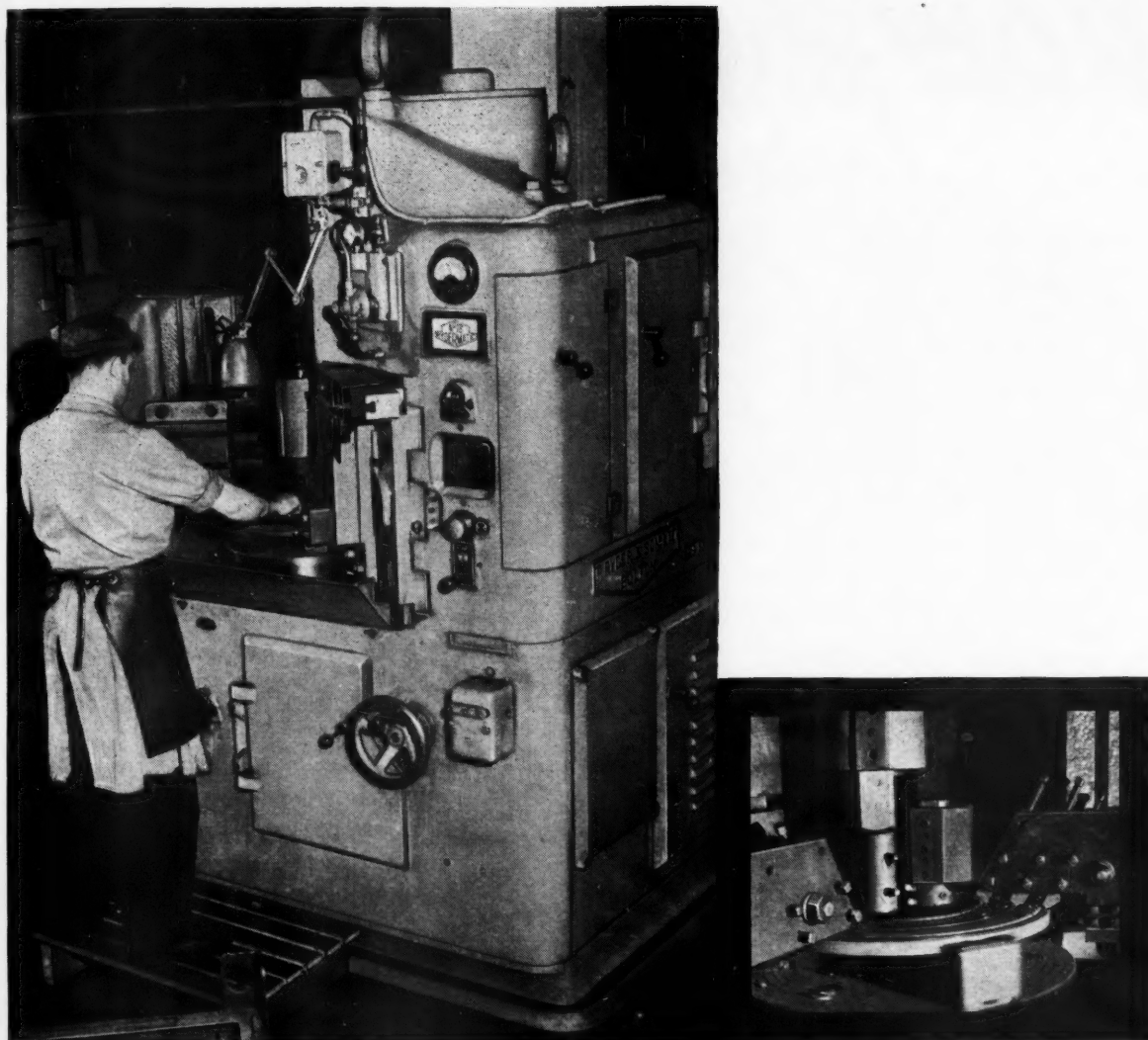
A 'Junior' type machine supplied to a Midlands Motor Car Works.

Dawson

**DE-GREASING
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A Rotary Drum machine for removing swarf and grease from small components.





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You'll find RYDERMATICS at Fords—

MACHINING TRACTOR CLUTCH PLATES

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PRICE £3.15.0 including one tip

Advantages of these 'Throw-Away' tip tools are as follows:

- 1 No Regrinding.
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PATENT CALIPER GAUGE MODEL 52



Each month one of the seven main advantages of this fine precision instrument will be described.

- Many different gauging positions can be obtained.
- The anvils are set so that they do not roll.
- All shearing action is eliminated.
- Particularly suitable for gauging shouldered work.
- Can be used for either left or right hand threads.
- ★ • Particularly suitable for the gauging of acme forms of thread.
- Can be supplied for "GO" only, or "NOT GO" only, or both "GO" & "NOT GO" combined.

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Owing to the design of the anvils and the neat layout of the frame, it is particularly suitable for the gauging of ACME types of thread.

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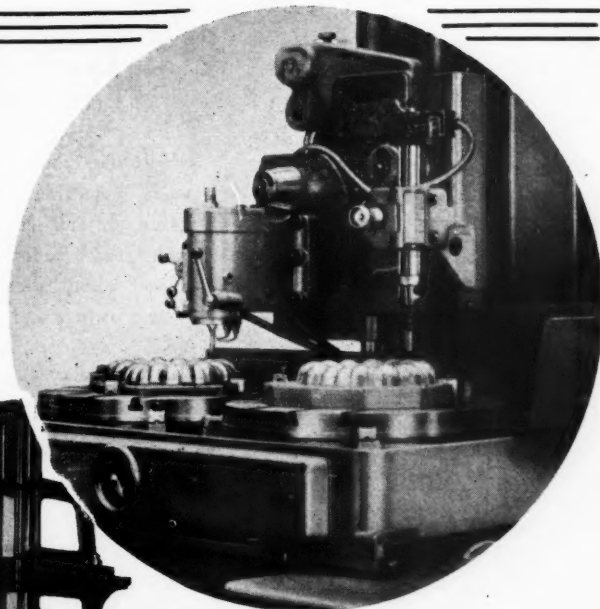
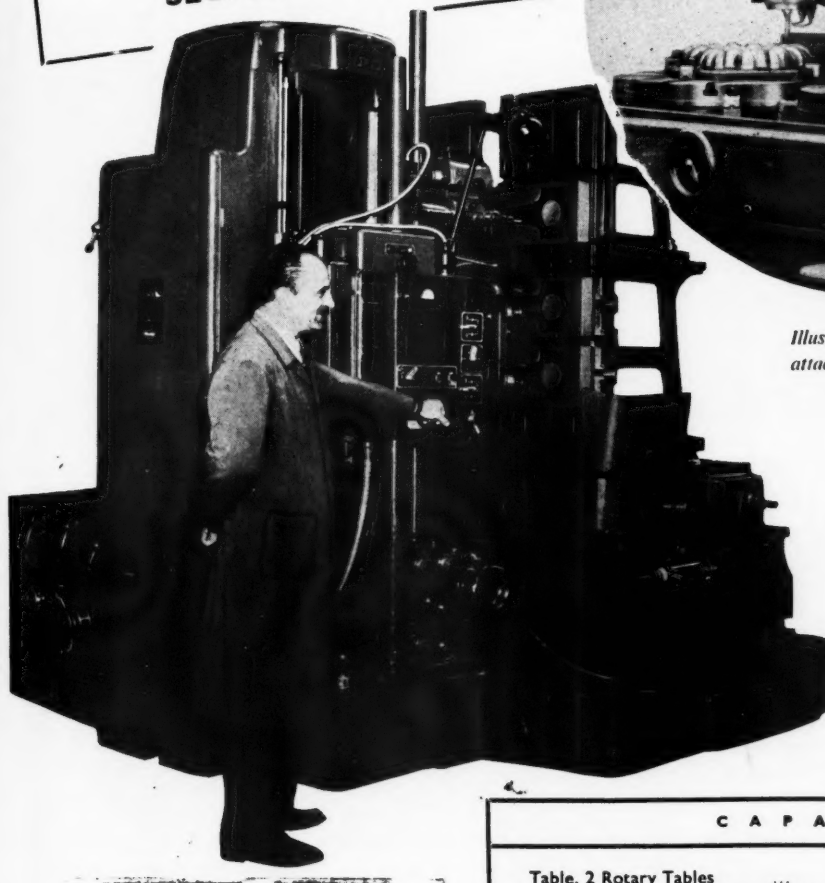


Illustration shows machine copying with vertical attachment fitted, and using the two rotary tables



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Vertical travel of spindle head	31½ in.
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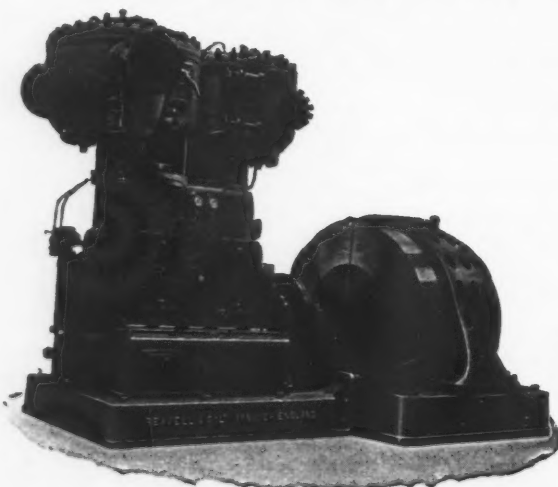
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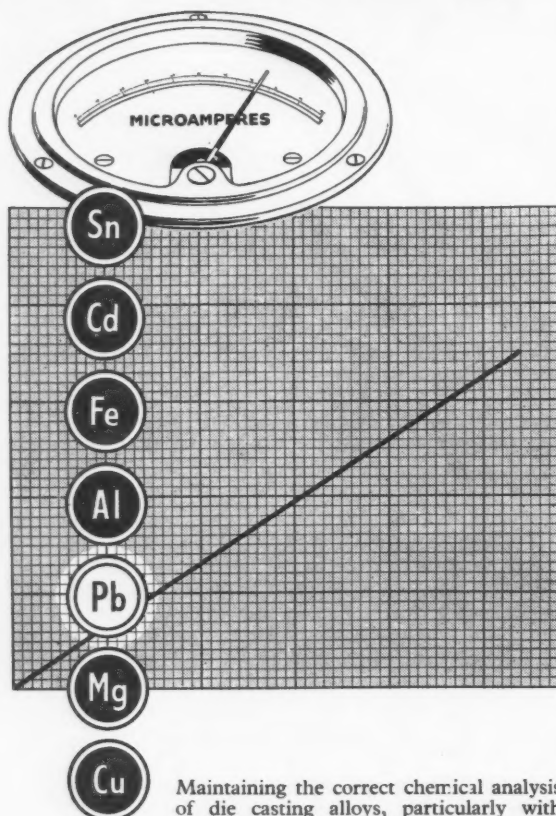
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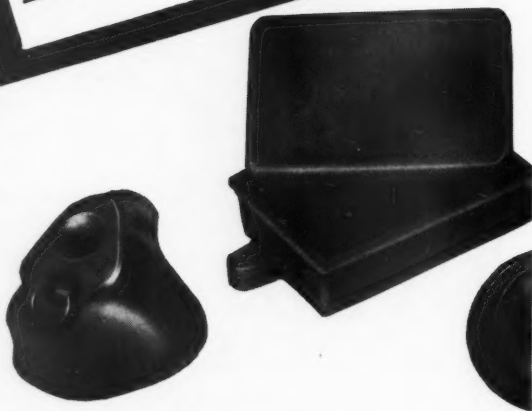
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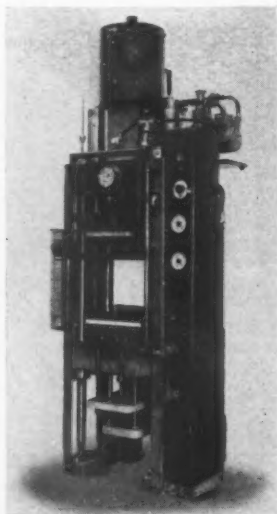
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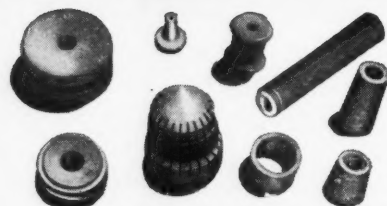
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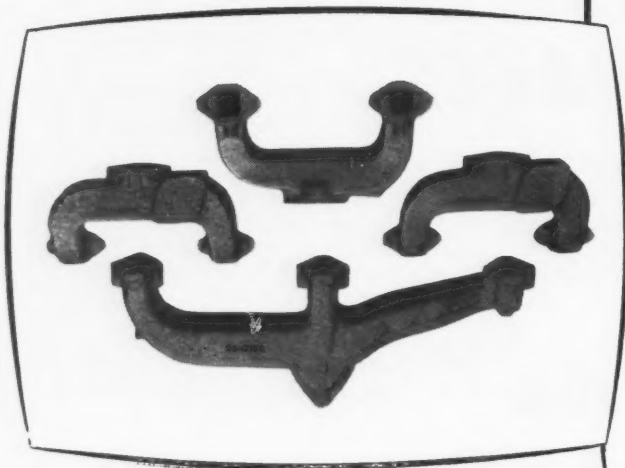
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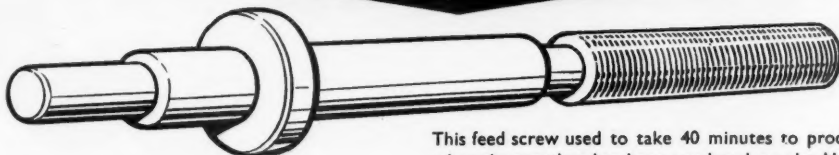
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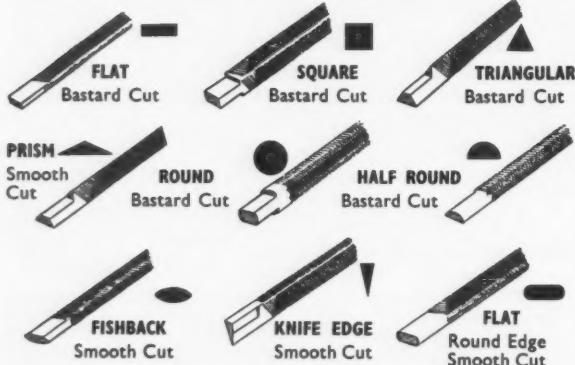
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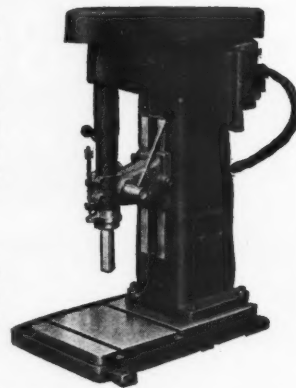
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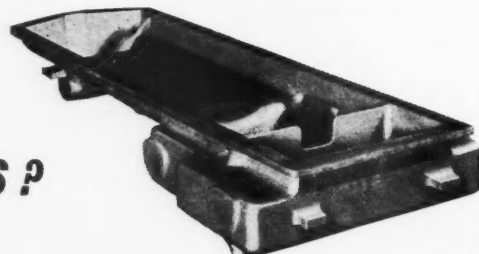
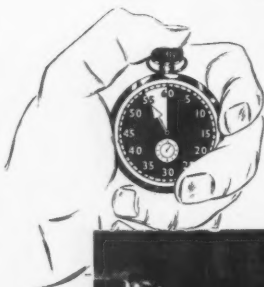
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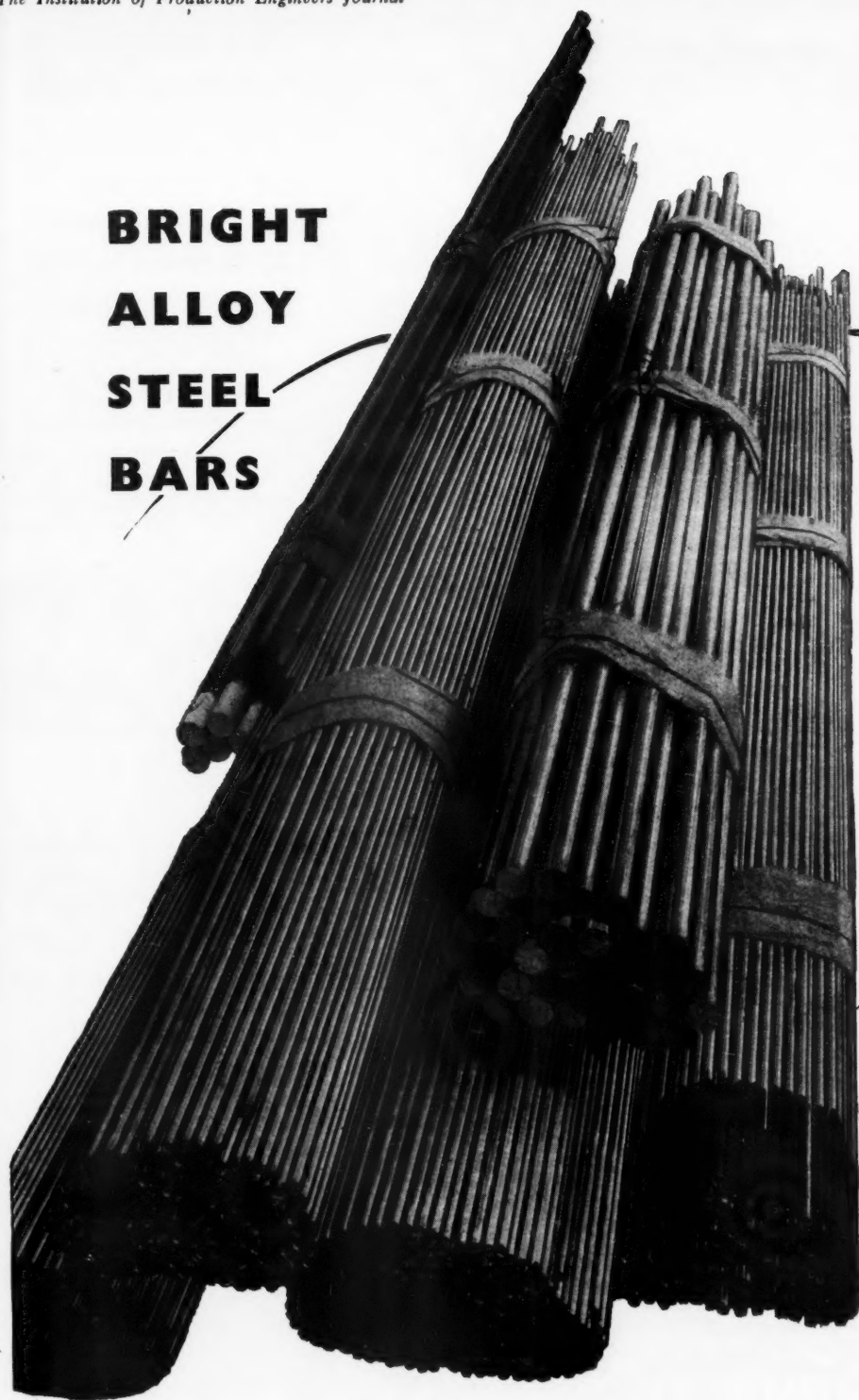
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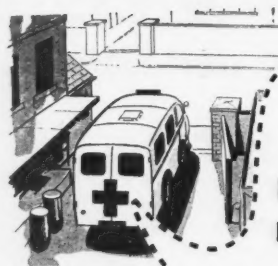
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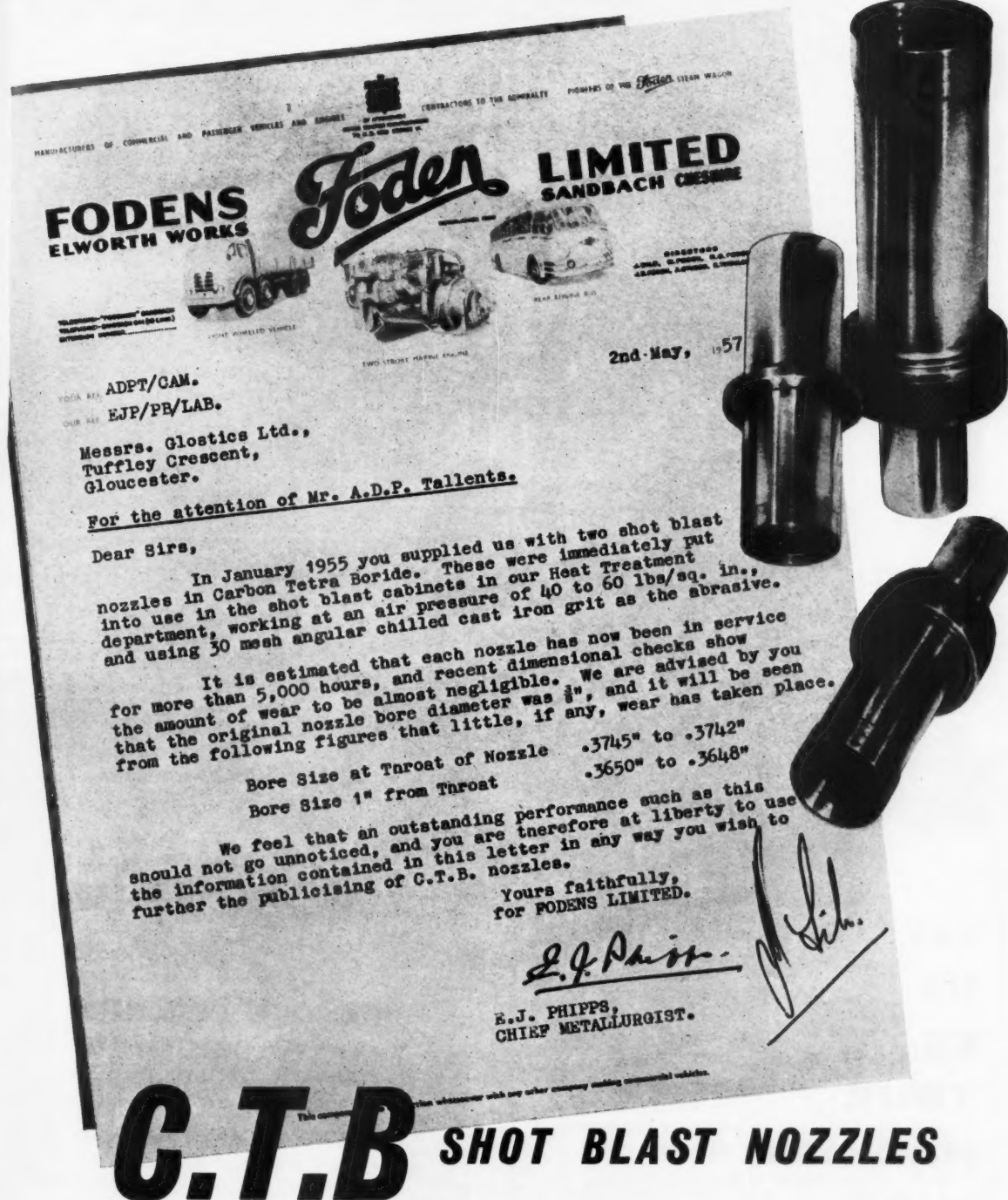
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Yours faithfully,
for FODENS LIMITED.

E.J. Phipps

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CHIEF METALLURGIST.

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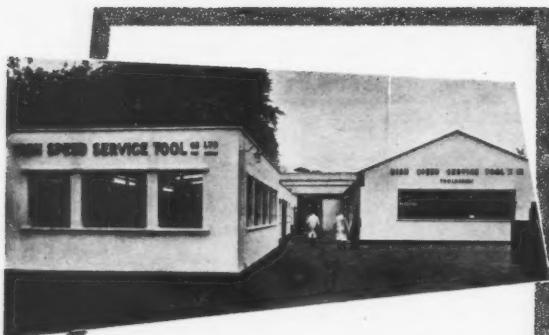
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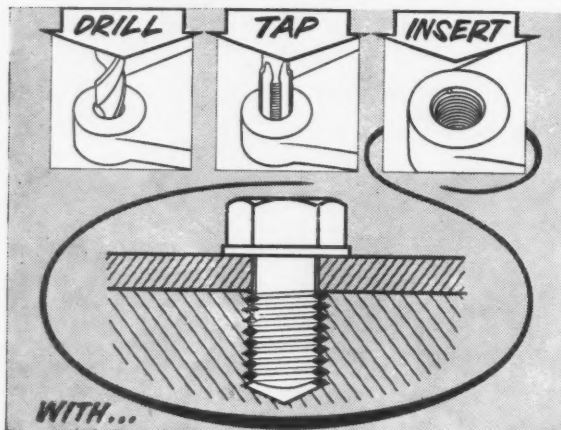


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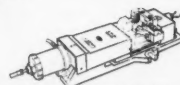
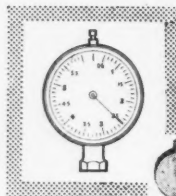
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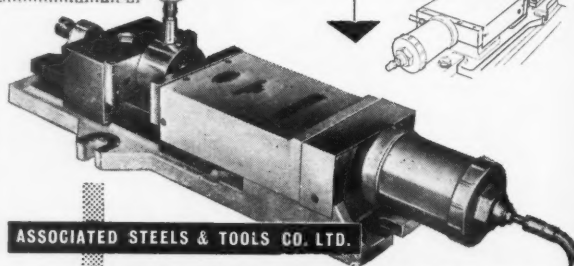
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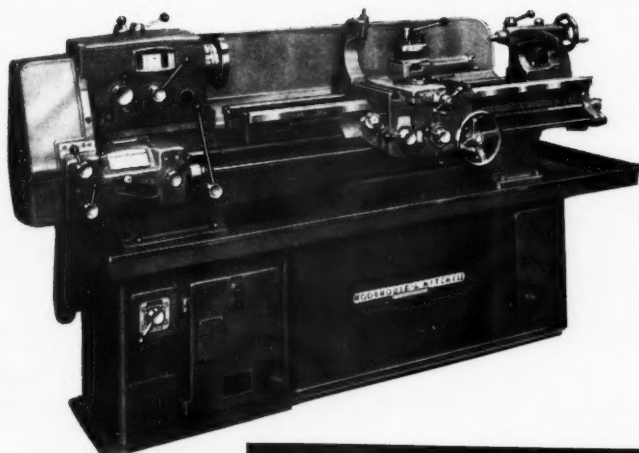
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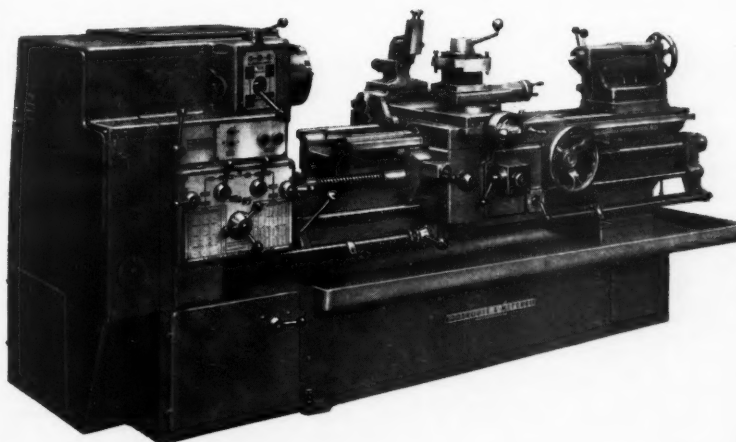


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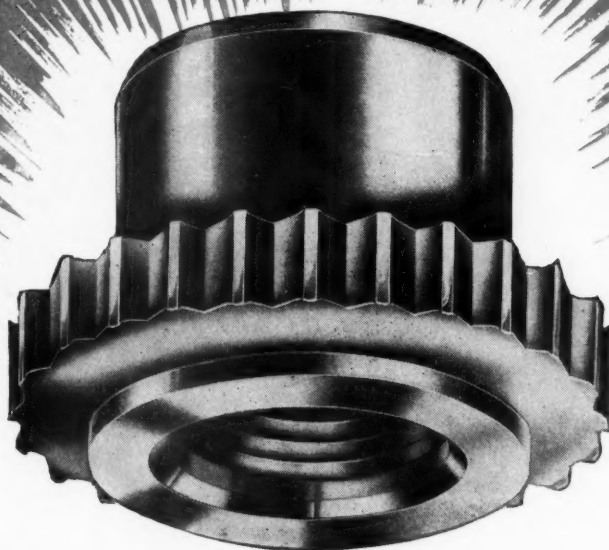
WM.20

INDEX TO ADVERTISEMENTS

	Page		Page		Page
Adcock & Shipley, Ltd. ...	iv	Factory Equipment Exhibition, The	XLIV	Napier, D., & Son, Ltd. ...	xxviii
Aero Research, Ltd. ...	LXXIII	Fawcett-Finney, Ltd. ...	—	National Industrial Fuel Efficiency Service ...	—
Ajax Machine Tool Co. Ltd. ...	LXXXVIII	Ferranti, Ltd. ...	LXXIV	Neill, James & Co. (Sheffield), Ltd. ...	xxx
Allen, Edgar, & Co. Ltd. ...	xxxvii	Firth Brown Tools, Ltd. ...	—	Newall, A. P., & Co. Ltd. ...	LXXIV
Aluminium Wire & Cable Co. Ltd. ...	—	Firth, Thos. & Brown, John, Ltd. ...	LXXXIX	Newall Group Sales, Ltd. ...	xxxiii
Andrews, Toledo, Ltd. ...	—	Flame Hardeners, Ltd. ...	—	New Conveyor Co. Ltd. ...	LXII
Armstrong Patents Co. Ltd. ...	xciv	Fletcher Miller, Ltd. ...	xcii	Norton Grinding Wheel Co. Ltd. ...	ix
Arrow Electric Switches, Ltd. ...	—	Ford Motor Co. Ltd. ...	xv		
Asquith, William, Ltd. ...	I	Fractional H.F. Motors, Ltd. ...	—	Ofrex Group ...	—
Associated Steels & Tools Co. Ltd. ...	xciv			Opperman Gears, Ltd. ...	—
		G.P.A. Tools & Gauges, Ltd. ...	—	Osborn, Samuel, & Co. Ltd. ...	x
B.I.P. Chemicals, Ltd. ...	—	Gas Council, The ...	<i>Outside Back Cover</i>	Park Gate Iron & Steel Co. Ltd. ...	—
B.S.A. Tools, Ltd. ...	LXV	Gauge & Tool Makers' Association, The ...	xviii	Parkinson, J., & Son (Shipley), Ltd. ...	—
Baird & Tatlock (London), Ltd. ...	—	Gledhill-Brook Time Recorders, Ltd. ...	—	Paterson Hughes Eng. Co. Ltd. ...	—
Baker, C., of Holborn, Ltd. ...	—	Glostics, Ltd. ...	xcI	Philips Electrical, Ltd. ...	LIV
Barber & Colman, Ltd. ...	—	Guest, Keen & Nettlefolds (Midlands), Ltd. ...	—	Plannair, Ltd. ...	xciii
Barracrough, R. W., Ltd. ...	—	Guylee, Frank, & Son, Ltd. ...	—	Power Jacks, Ltd. ...	—
Benton & Stone, Ltd. ...	—			Precision Grinding, Ltd. ...	—
Birlec, Ltd. ...	xxii	Hale & Hale (Tipton), Ltd. ...	—	Pryor, Edward, & Son, Ltd. ...	—
Birmingham Aluminium Casting (1903) Co. Ltd. ...	iii	Harrison, T. S. & Sons, Ltd. ...	LXXXVII	Rack Engineering, Ltd. ...	xiv
Black & Decker, Ltd. ...	LVIII	Harris Tools, John, Ltd. ...	—	Ratliffe, F. S. (Rochdale), Ltd. ...	—
Bolton Railway Wagon & Ironworks Co. Ltd. ...	XL	Heenan & Froude, Ltd. ...	—	Rawplugh Co. Ltd., The ...	vii
Bratby & Hincliffe, Ltd. ...	—	Herbert, Alfred, Ltd. ...	LV	Reavell & Co. Ltd. ...	LXXX
Bray Accessories, Ltd. ...	—	High Speed Service Tool Co. Ltd. ...	XCIV	Reliance Gear & Eng. Co. (Salford), Ltd. ...	—
British Aero Components, Ltd. ...	xxxI	Hilger & Watts, Ltd. ...	LXXII	Rockwell Machine Tool Co. Ltd. ...	XXV, LXXXVIII
British Die Casting & Engineering Co. Ltd. ...	LXI	Holman Bros., Ltd. ...	XXIII	Rowland, F. E., & Co. Ltd. ...	—
British Electrical Development Association, The ...	—	Holt, James (Engineers), Ltd. ...	—	Russell, S., & Sons, Ltd. ...	—
British MonoRail, Ltd. ...	LXXXI	Hordern, Mason & Edwards, Ltd. ...	—	Ryder, Thos., & Son, Ltd. ...	LXXVII
British Oxygen Gases, Ltd. ...	xi	Horstmann Gear Co. Ltd., The ...	LXXXVIII	Sandvik Swedish Steels, Ltd. ...	—
British Tabulating Machine Co. Ltd. ...	XXIN	Hydraulics & Pneumatics, Ltd. ...	xcii	Saville, J. J., & Co. Ltd. ...	xvii
British Thomson-Houston Co. Ltd. ...	—	Hymatic Engineering Co. Ltd., The ...	—	Scrivenner, Arthur, Ltd. ...	—
British Timken, Ltd. ...	—			Selson Machine Tool Co. Ltd., The ...	LXVII
Brockhouse, J., & Co. Ltd. ...	LXXII	Ilford, Ltd. ...	XXXVII	Sentinel (Shrewsbury), Ltd. ...	XXIV
Broom & Wade, Ltd. ...	—	Impregnated Diamond Products Ltd. ...	xvi	Sheffield Forge & Rolling Mills Co. Ltd. ...	—
Brown, David, Corpn. (Sales) Ltd., The ...	LXXXIV	Instrument Screw Co. Ltd. ...	—	Shell Chemical Co. Ltd. ...	—
Brown & Ward, Ltd. ...	—	Integra, Leeds & Northrup, Ltd. ...	—	Shell-Mex & B.P., Ltd. ...	LI
Burton Griffiths & Co. Ltd. ...	LXV			Sheepbridge Equipment, Ltd. ...	—
Butler Machine Tool Co. Ltd., The ...	LXX	Jessop, Wm., & Sons, Ltd. ...	xvii, LX	Slack & Parr, Ltd. ...	—
		Johansson, C. E., Ltd. ...	Li	Smart & Brown (Machine Tools), Ltd. ...	—
Catmur Machine Tool Corpn., Ltd. ...	—	Jones, E. H. (Machine Tools), Ltd. ...	—	Smith, C. & B., Ltd. ...	LXXV
Centec Machine Tools, Ltd. ...	—	Kaye, E. & E., Ltd. ...	—	Snow & Co. Ltd. ...	LXXXVI
Churchill, Charles & Co. Ltd. ...	—	Kearns, H. W., & Co. Ltd. ...	—	Société Genevoise, Ltd. ...	xxvi, xxvii
Churchill Machine Tool Co. Ltd. ...	XLVIII	King, Geo. W., Ltd. ...	—	Sogenique (Service), Ltd. ...	—
Climax Rock Drill & Eng. Works Ltd. ...	xix	Kingsbury, Geo. & Co. Ltd. ...	viii	Sparcatron ...	LXVIII
Cohen, Geo., Sons & Co. Ltd. ...	—			Sparklets, Ltd. ...	LXXXII
Concentric Manufacturing Co. Ltd. ...	—	Lang, John & Sons, Ltd. ...	XLVII	Spencer & Halstead, Ltd. ...	LVII
Council of Industrial Design ...	xciv	Lang Pneumatic, Ltd. ...	XX	Square, D., Ltd. ...	xiii
Coventry Climax Engines, Ltd. ...	—	Lapointe Machine Tool Co. Ltd. ...	LXNI	Sternol, Ltd. ...	LXXXIII
Coventry Gauge & Tool Co. Ltd. ...	—	Ley's Malleable Castings Co. Ltd. ...	—	Sunbeam Anti-Corrosives, Ltd. ...	—
Cow, P. B., & Co. Ltd. ...	LXXXII	Lincoln Electric Co. Ltd., The ...	—	Swift, Geo., & Sons, Ltd. ...	—
Crawford Collets, Ltd. ...	—	Lloyd, F. H. & Co. Ltd. ...	—	Swift Summerskill, Ltd. ...	—
Crofts (Engineers), Ltd. ...	—	Lloyd, Richard, Ltd. ...	XXXII	Talbot Tool Co. Ltd., The ...	—
Crompton Parkinson, Ltd. ...	—	Lodge Plugs, Ltd. ...	LXXXVI	Teddington Industrial Equipment Ltd. ...	—
Crosland, William, Ltd. ...	LXXX	London Oil Refining Co. Ltd., The ...	LXXXIV	Terry, Herbert, & Sons, Ltd. ...	LVI
		Lund, John, Ltd. ...	XXXVI	Town, Frederick & Sons, Ltd. ...	—
				Udal, J. P., Ltd. ...	xc
Darwins Bright Steels, Ltd. ...	—	M.H.H. Engineering Co. Ltd. ...	—	Unbrako Socket Screw Co. Ltd. ...	—
Darwins Group, The ...	—	Macready's Metal Co. Ltd. ...	XL	Universal Tools, Ltd. ...	—
Dawe Instruments, Ltd. ...	—	Magnesium Elektron Co. Ltd. ...	—		
Dawson Bros., Ltd. ...	LXXVI	McGraw-Hill Publishing Co. Ltd. ...	—	Vacu-Blast, Ltd. ...	—
Dean Smith & Grace, Ltd. ...	XXXV	Manganese Bronze & Brass Co. Ltd. ...	—	Van Moppes & Sons (Diamond Tools), Ltd. ...	XXXIV
Dowding & Doll, Ltd. ...	LXIX	Marbaix, Gaston E., Ltd. ...	LIJI	Vaughan Associates, Ltd. ...	LXIII
Drummond Asquith (Sales), Ltd. ...	—	Markland Scowcroft, Ltd. ...	LXXVI		
Drummond Bros., Ltd. ...	LI	Marsden & Shiers, Ltd. ...	xcii	Wadkin, Ltd. ...	LXXXVIII
		Martonair, Ltd. ...	LX	Wakefield-Dick Industrial Oils, Ltd. ...	XLIII
E.M.I. Electronics, Ltd. ...	—	Mechanical Handling Exhibition ...	xii	Ward, H. W., & Co. Ltd. ...	XLVI
E.N.V. Engineering Co. Ltd. ...	xc	Metropolitan-Vickers Electrical Co. Ltd. ...	—	Ward, Thos. W., Ltd. ...	—
Edibrac, Ltd. ...	LXXVIII	Midgley & Sutcliffe, Ltd. ...	xc	Webster & Bennett, Ltd. ...	vi
Elgar Machine Tool Co. Ltd. ...	LXXIX	Mining & Chemical Products, Ltd. ...	LXIV	Wickman, Ltd. ...	XLII
English Electric Co. Ltd., The ...	—	Mobil Oil Co. Ltd. ...	XLV	Wild-Barfield Electrical Furnaces, Ltd. ...	LXVI
English Steel Tool Corpn., Ltd. ...	LXXXV	Monks & Crane, Ltd. ...	—	Woodhouse & Mitchell ...	—
Exors of James Mills, Ltd. ...	—	Morris, B. O., Ltd. ...	XXI		

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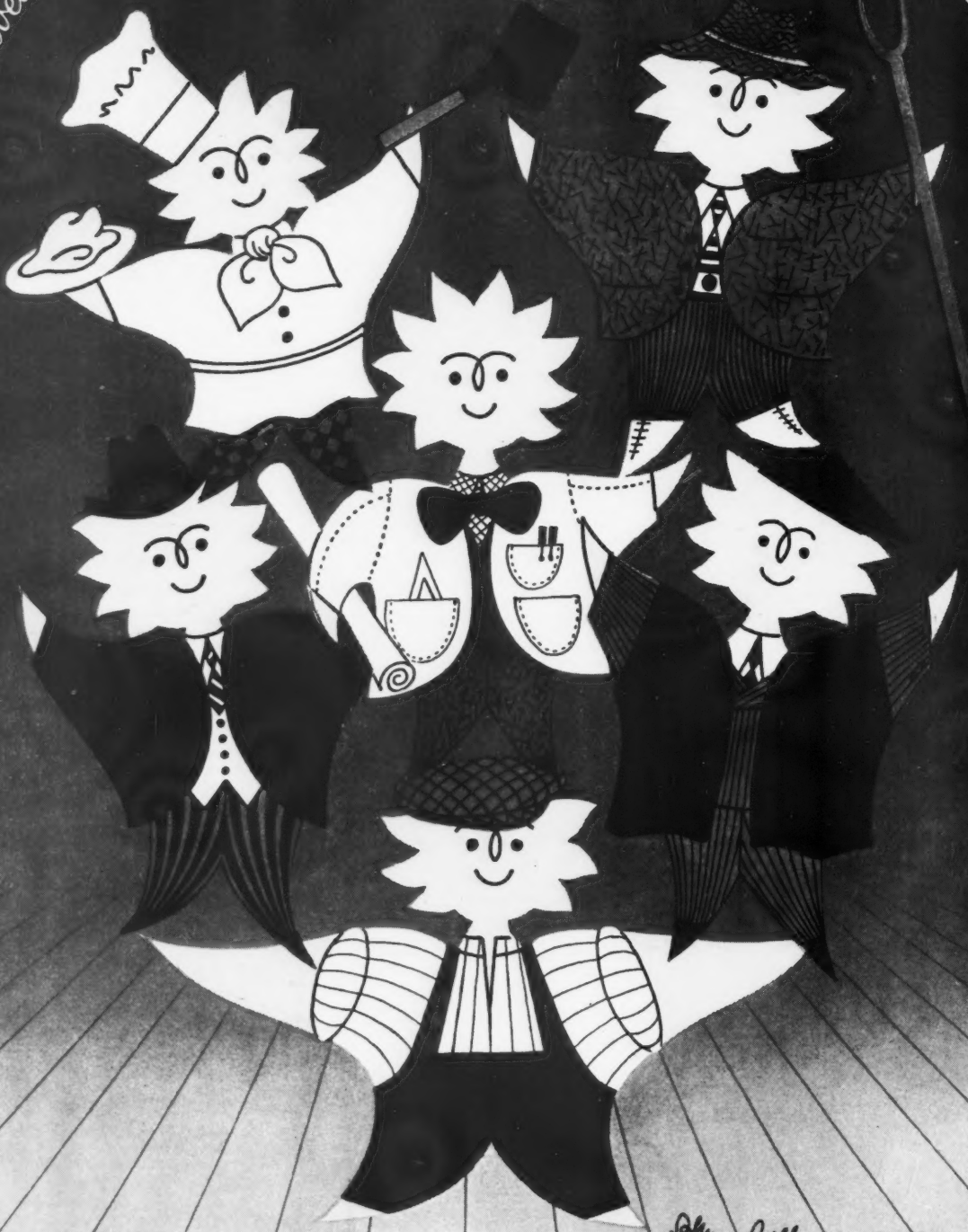
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